THE
EMERGING PSYCHOLOGICAL FRAME OF REFERENCE

For

OUR SCHOOL SCIENCE EDUCATION

By

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C O N T E N T S .

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FOREWORD.

For the last two years or so, Professor N.Vaidya is working on an ERIC(NCERT) project titled THE DETERMINATION AND DEVELOPMENT OF SCHEMES OF THOUGHT IN SCIENCE DURING ADOLESCENCE. This project attempts to link the significant concepts of science to the intellectual growth of children in the Piagetian frame. Being a longitudinal study, the work on this project is still in progress.

In an endeavour to clarify the problem, Prof. Vaidya has consolidated literature in this area under the title: The Emerging Psychological Frame of Reference For Our School Science Education. During the last several years, the Ministry of Education, NCERT, State Institutes of Science Education and other voluntary agencies have been trying to revamp science education in our country, yet theoretical literature in this area is not available in adequate quantities which deals with concept formation, problem solving, logical thinking and acceleration of thought etc. Keeping in mind limitations of the provincial town like AJMER (Rajasthan), it is quite possible that a few significant studies whether Indian or Foreign may have been missed. Also, there may be a gap in the presentation of ideas. Prof. Vaidya is aware of these limitations.

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Being a document for restricted circulation, I am pleased to send it to you for your critical comments as well as advice for the benefit of Prof. Vaidya,. Your comments and advice will go a long way in improving this document. I am further pleased to inform you that before this document is out, Prof. Vaidya has already started working on the second version of this document. The reason for this is that Prof. Vaidya has been able to procure very recently some additional studies in this area which could not be included in this.

Prof. Vaidya needs critical, incisive yet considered comments from you on this first effort. Against the light of your valuable advice, he will be further available to improve the quality of his first version of the draft. Precisely for this reason, I am pleased to send a copy of this document to you. I am sure you will find going through this document a rewarding experience.

PROF. R. P. SINGH
PRINCIPAL

[illegible]

. Delimitation of Scope.

Human thinking is as vast and deep as sea. It has given us our present day scientific and literary culture:an aspect whose roots can be traced to the distant past, not a difficult task. But more difficult, intriguing and mysterious has been the very investigation of the phenomenon of human thinking for in its entire history, It is only in this century that the experimental science' began to interest itself in thought' (1) . David Rapport aptly remarks:

> The knowledge that thinking has conquered for humanity is vast, yet our knowledge of thinking is scant. It might seem that thinking eludes its own eye. But this may be an illusion, and the eye is perhaps not searching but only staring... Whatever its nature, thinking comes to the point of invention, discovery and creation only in some

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human things ,it serves most of us merely to the point of at least understanding what the few have created. And yet the dream stuff out of which world-changing thought is made is present in all of us, in the sentence-fragments of the brain injured, in the delusions of the schizopherenic and in the babbling of the child. This is its enigma(2).

He further reminds the readers of his childhood experimences at school when he either hesitated or failed to anticipate steps done for him by the teacher. Why? He further adds:

> Disappointed and puzzled, I ask myself why I cannot foretell the step, when it is so self-evident after I see it done. I must have asked this question countless times before, when impressed and hurt in pride by adult omniscience. But I have asked it continuously ever since: the attendant shame and bitterness may have faded, the curiosity and puzzlement have not(2).

The above statement adds to the difficulties of any reviewer while surveying theoretical stand points as well as specific researches on human thinking even with special reference to science education at the school level. Prima facie, there are four ways to delimit the range and scope of this contemplated survey: by historical

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survey, by subject matter, that is, by drawing scientific concepts from different branches of scientific knowledge by purpose; and method with little reference to scientific attitudes and personality variables. At its best, these four categories are not independent of each other; and hence can be regarded as dependent dimensions which need to be fused with a view to see the entire spectrum of human thought through a single crystal ball, quite an impossible task! By narrowing down, it may become feasible to attempt this survey; and consequently, all studies relating to animal thinking, human thinking (autistic, associative, creative and critical); relationship between language and thinking, concept formation including concept attainment as well as involving any predictive relationship, abstraction, generalization, memory, imagination, attention, believing, judging, comparative effectiveness of teaching methods or techniques, transfer of training or learning tasks, perception and rival theories of learning have been excluded straight away from this preview. The reason for this is simple because the present study deals with cognitive processes of thought from the developmental point of view. It is not only that the research literature is vast but also the ' basic problem of cognition is to describe the growth of concepts and to detail the processes of thought by which these concepts are

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acquired and put to use" (3). Exception, however, has only been made where the reference is pertinent, relevant or incidental having some direct bearing on the problem. Lastly, on examining the relevant literature on thinking, one finds that it has been investigated from several view points: S.R.Theories; Gestalt Psychology; Phenomenological Theory; The Geneva School; Factor analysis; Acceleration of mental development, and Information Processing. If the philosophical, psychological and epistemological rootings of Gestalt as well as Geneva school are ignored, the present study makes use of three basic mentions underlying these two psychologies in the formulation of problems used in this study for investigating adolescent thinking, these three basic notions being; insight, productive thought and stage concept. In summary, the basic structure for a survey of this type is suggested below under the following heads:

Section A

1. Nature and Definitions of Thinking.
2. Problems Posed in the Field.
3. Concluding Statement.

Section B.

4. Theoretical stand-points
   - (i) Introduction
   - (ii) S.R.Theories

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Section C.

S E C T I O N - A .

1. Nature and Definitions of Thinking:

Since, the times of Aristotle, philosophers and logicians have not only investigated thinking in terms of its product but also have developed their own laws of thought. Examples are; Laws of identity; Contradiction; and Excluded Middle. At the turn of the century, psychologists placed lot of faith in faculty psychology which regarded mind as made up of several individual abilities, each amendable to training in isolation. Initial success with it resulted in the theory of formal discipline, a major educational achievement which was exploded later on. The pure psychologists both European and American, investigated thinking from their varied stand points with little attention paid to problems of classroom instruction. The educational psychologists,

psychologists, on the other hand, examined thinking through the medium of problem solving but the actual process of thinking eluded their attention(4). For example, C.E.Spearman regarded the following three principles of significance " apprehension of experience, education of relations and education of correlates" quite sufficient for explaining the entire spectrum of intellectual behaviour(5), On surveying the relevant literature, it appears that the following aspects of thinking have received attention over the years, that is, the term thinking has been referred or applied to: " abstracting, analysing, comparing, conceiving, deducing, defining, estimating, generalizing, guessing, imagining, judging, knowing, opining, reasoning, recalling, recognizing, reflecting, remembering, searching for conclusions and understanding, " a sort of general meaning. In its restricted use, the same term has been applied to ' determined course of ideas, feeling, formulation and assertion of propositions, percepts and vocal sound" (6) Symmond has listed nineteen types of thinking such as learning, meaning, stating relationships, defining etc. (7). Humphrey has equated it with problem solving(8). Burt and his students, have regarded it a 'hierarchy of thinking abilities comprising of relation, association, perception and sensation" etc.(9).Gestalt psychologists have emphasized its perceptual and problem solving aspects (10). Bartlett has regarded it as high level

skill in which ' symbols, words, numbers, shapes, colours, tones, supplement and may take the place of bodily movements"(10). E.A. Peel has distinguished among four kinds of thinking: Thematic, Explanatory, Productive and Integrative and adds that ' free association, remembering, reverie, faciful association, punning, solving cross word clues" are other aspects of human thought, which have not been classified in any one of the above mentioned categories (11). D.H.Russell has suggested his own scheme starting with stimulus patterns (internal or external) through materials of thinking(perceptions, images, memories and concepts), processes in thinking (perceptual thinking, associative thinking, problem solving and creative thinking) to products of conclusions implying thereby that abilities in thinking, techniques, habits and devices are amenable to learning(12). In the Encyclopedia of Educational Research, Wilhelm Reitz, while surveying the area of thinking, has hypothesized that whereas the materials of thinking are numerous, the number of processes appear to be few; and here, ' research data being incomplete and scattered' (13). From the above it is clear that it is pretty difficult to define thinking and even when defined, its explanatory concepts themselves become

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Dr. N. Vaidya,
Prof. of Education

-6 NOV 1979

5th November, 1979.

N.F. Edu/Exi
11405

Dear Prof. Wanchoo,

Please find enclosed a copy of my recent material for your kind perusal.

With kind regards,

Yours sincerely,

NVaidya
(N. Vaidya)

Encl. As above.

Prof. V.N. Wanchoo,
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suspect and consequently require further explanations. The whole position on thinking is well summarized in the words of Hearnshaw in Recent Studies in the Psychology of Thinking:

> Thinking- highly organized and balanced activity dependent upon the coordination of a large number of subordinate activities under favourable conditions is inseparably linked with the personality traits of its thinker. This complex activity is difficult to investigate if it remains ghost like but, on the other hand, if it is regarded as a skill (or a group of skills)which is organization, " a viewpoint quite in conformity with Piaget's genetic findings, with the evidence pointing to the motor accompaniments of thought and the results of perceptual studies emphasizing the dynamic nature of perception and the acquired character of all but the simplest perceptual structures'; then it is possible to investigate thinking by trying to bear upon the psychology of thinking all that the psychologist has learned about learning keeping in mind that skills are essentially activities and skills are learned and their basic feature is organization(13).

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The central question on thinking has been very excellently put by Hearnshaw for it is possible to study both the processes of generalization and discrimination experimentally, a step ahead of ' deu ex machina' in the form of insight propounded by Gestalt psychologists(14).

It will be irreverent if John Dewey's contribution in narrowing down the concept of thinking as problem solving is not acknowledged by which he avoided the 'pitfalls of both traditional empiricism and a priori rationalism' (15). He, thus, brought out Ryle's ghost in the machine for empirical examination tied to purpose and consequently subject to reflection. He regarded thinking as a function of an'obstacle in the way of goal directed activity(14). To quote Dewey:

> Sensory qualities experienced through vision have their cognitive status and office, not (as sensational empiricism holds) in and out of themselves in isolation, or as merely forced upon attention, but because they are the consequences of definite and intentionally performed operations. Only in connection with the intent, or idea, of these operations do they amount to anything, either as disclosing any fact or giving test and proof of any theory. The rationalist school was right in so far as it insisted that sensory qualities are

Contd...10..

significant for knowledge only when connected by means of ideas. But they were wrong in locating the connecting ideas in intellect apart from experience. Connection is instituted through operations which define idea and operations are as much matters of experience as are sensory qualities(15).

He thus stripped Thinking of its philosophical aspects as outlined by Descartes, John Locke and J.S.Mill; and gave it a form of physical process of natural sciences manifested in man while coping with his environment(14). On the basis of introspection, he suggested five steps in thinking which can quite adequately explain most of our thinking. This lead by Dewey has been further followed by many practical workers in the field, a few to mention are: Burt(1928); Johnson (1944); Polya(1945); Humphrey(1948); Bloom(1950); Burrack (1950): Hoffman and his Co-workers(1951); Vinacke (1952); J.Stanley Gray (1956); Mill and Dean(1960); Oad and Vaidya (1975). It should not be lost sight of that these steps have been hypothesized for the sake of convenience(17). One can identify any number of stages in thinking depending upon the nature of problem to be investigated (17). For illustration, let us consider the steps as suggested by Dewey, Humphrey and Mills & Dean.

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Dewey (1910).

(a) A felt difficulty

(b) Its location and definition

(c) Suggestion of possible solution

(d) Development of reasoning of the bearing of suggestions.

(e)Further observation and experiment leading to its acceptance of rejection(15).

Humphrey(1948).

Directed thinking involves:

(a) A Problem Situation.

(b) Motivation factors

(c) Trial & error

(d) Use of association & images

(e) A flash of insight.

(f) Some application in action(1).

Mills & Dean(1960).

(a) A difficulty is recognized.

(b) The problem is clarified and defined.

(c) A search for a clue is made

(d) Various suggestions are made and are evaluated and tried out.

(e) Whereas practice in the definition of problem involves problem survey, problem description, problem discussion, problem limitation, planning for action and further analysis and limitation(16).

contd..12..

Oad & Vaidya (1975).

(a) The appearance, disappearance and appearance of the problematic situation.

(b) Vague understanding and clarification of the problematic situation.

(c) Blunt Formulation of the problem.

(d) Trial and error attacks

(e) Proposing hypotheses.

(f) Screening hypotheses and selecting testable hypotheses.

(g) Testing hypotheses through control experiments.

(h) Obtaining relevant hypotheses.

Mathematizing
Insight into the nature of proof
Determining limiting situations

Verification
Exploring further varied experimental materials exploring further varied methods of attack.

Final Formulation of the problem and its solution.

Application

Repetition of the cycle in the face of unknown difficulties(18)

It may be mentioned that these steps like logically obtained educational principles not only do not clarify any psychological principles but also do not follow each other in a fixed sequence. They are, in fact, 'simplified, idealized versions of what may take place

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in problem solving' or reflective thinking. They are more in the nature of heuristic methods rather than logical proofs. They only help us to see the problem a bit more transparently in all its varied aspects. Karl Duncker through his studies on Problem Solving, gave these steps the more generalized name of Search Model which may be little different from Strategy (Goodnow, Austin & Bruner) and Key Factor as propounded by Guilford, Merriefield, Christensen and Frick in ' determining efficiency of creative thinking'(18) Lastly ,with special reference to school subjects, Peel distinguished among four kinds of thinking, namely, Thematic (free from any practical requirement); Explanatory, Productive and Integrative(11). Productive Thinking comes very close to Thinking when it is equated with problem solving. It is said to have taken place 'when the attack on a problem is taken beyond the stage of explanation and used to modify the situation so that the original problem is removed'(6,11). In one form or another, it enters into every school subject. Its chief distinguishing features, according to Peel, are:

(a) It contains an element of forward thinking.

(b) It becomes effective by changing the problem situations materially in order to achieve solutions.

Contd...14..

(c) Some new problems may be solved by restating them in the light of established knowledge.

(d) These situations may be material, social or personal (11).

From the above account, it is safe to conclude that it is not possible to define thinking operationally even in the highly restricted sense but it is still possible to guess what it is not in that context. In other words, it is a task oriented situation, which stimulates thinking right from the moment the task is presented to the subject until the moment it is finally solved by him. The problem is not that simple as the following section on, 'Problems Posed in the Field ' will show.

2. Problems posed in the Field.

It is necessary to go ahead on the journey of investigating thinking itself for the venture may pay off in the long run. Where to start? and which road to take? are the basic problems to be tackled first before taking the first step on this journey whose end is unknown. George Humphrey in Fifty Years Experiment on Thinking remarked that the entire past adventure on thinking has not been at all fruitless for we now know, at least, the kind of road we have yet to travel(1).

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thinking in relation to the past history of the individual. Or' what makes people attack problems', according to Cohen, will contribute to our understanding of problem solving(19). According to Johnson, an adequate understanding of problem solving requires' knowledge of the development of even higher organization (as compared to concept formation) of data such as the concept of self, points of view, frames of reference, and more complex patterns of inter-relationship illustrated by the family pattern, the syllogism and the pattern of industrial experience' (6). For Vinacke, the whole area awaits invasion through case study approach with a view to collect as well as to interrelate as many aspects of performance as possible in as many situations as practicable(6). Similarly, Carl P.Duncan, D.Wheeler, L.A.Peel, R.H.Ennis, M.V.Travers and F.G.Watson have emphasized the importance of investigating thinking (problem solving) in relation to some outside variables like intelligence, personality variables, socio-economic status, motivation, ego involvement and set, a few out of the many to mention(20). Along with these variables,it is also necessary to study generalization of formal reasoning of thinking in Gestaltean as well as Piagetian Contexts. Secondly, very little is known about the overall psychological structure of any

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school subject. Thirdly, these individual studies are required to be carried out in as many different subjects as well as situations as possible. Fourthly, the stage concept as propounded by Piaget also needs to be investigated at depth along with the emergence of various mental operations at various age levels. Lastly, there are several difficulties, which need to be tackled or mastered before we can understand clearly the nature of thinking: problem solving, concept development and attainment. Here, the main difficulty lies in our failure to understand the sequence of reasoning from the very early childhood to late adolescence, not only within each age-group but also across the various age-groups over a very wide I.Q. range. It is of interest to point out that even the restricted behaviour like problem-solving, according to A. Dietz Maureen and George D.Kenneth, has been investigated under various definitions(21). The field of human thinking as a whole poses certain fundamental problems which are yet to be investigated even partially before we can fully understand the basic assumption underlying human thought processes(20). It is very likely that answers to these questions will have an import equal to the concept of Periodic Table in Chemistry or the concept of Quanta in Atomic Physics

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for the whole field of psychology as well. Let us now state below a few problems posed in cognitive psychology and the psychological structures of science by the various workers.

(a) Piaget is a mine of ideas on cognitive thinking, necessitating vast experimental educational research. He goes far beyond on the nature of intelligence, what A.Binet characterized wittily as 'It is what my tests measure' (23). In addition to the role of experience, it is necessary to have information on the extent of adult's influence on children as well as their mutual influence on each other. Not long ago, J.S.Bruner said that, in principle, any thing can be taught to any body in some honest form. This principle further needs to be examined empirically for Does it Imply Elimination of Sequences? To quote the large problem which first needs to be understood developmentally rather than psychometrically in the words of Jean Piaget in the Growth of Logical Thinking and Main trends of Research in the Social & Human Sciences (Part I):

(i) It is surprising that inspite of the large number of excellent works which have been published on the effective and social life of the adolescent-we hardly need remind the reader of the studies of Stanley Hall, Compayre, Mendousse, Spranger, Charlotte Buhler, Landis, Wayne Dennis, Brooks, Fleming, or

contd..18...

Debesse, or those by psychoanalysts such as Anna Freud and Helene Deutsch, and by sociologists and anthropologists such as Maulinowski and Margaret Mead, not to mention others-so little work has appeared on the adolescent's thinking(22).

(ii) As to the theory of intelligence,all these observations seem to lead to a number of conclusions that it is difficult to ignore. The first is that the intelligence is much richer than the aspects of which the subject becomes aware, for he is conscie ous only of the external findings of his intelligence, except, when through a systematic and retroactive reflexive process, logic and mathematics formalize, but generally without concerning themselves with their sources, structures whose natural roots are already in the intelligence in action. As to the average subject, he is aware of this intelligence only from its performance, for the operative structures elude him, as more over nearly all the mechanisms affecting his behaviour and even more so his organism. It is,therefore, for the observer to find out whether the structures do exist and to analyse them, but the subject is unaware of them as structures

discern only the operations used by him (and even then not all of them, for he constantly resorts to 'associativity' and 'distributivity' without realizing it, and the same is often the case with commutativity)....

We had to wait for psychogenetics and the discovery of the various preoperative and operative stages through which the child and the adolescent go before the specificity of intellectual structures could be established. However, this structuralism is only one of the two services rendered by psychogenetics. The other relates to constructivism and is not less essential. The operative structures of the intelligence are not innate, but slowly develop laboriously during the first fifteen years of life in the most favoured societies. If they are not already formed in the nervous system, neither are they in the physical world, where they would only have to be discovered. They therefore testify to a real construction, proceeding by stages, at each of which the results obtained at the preceding stage must first be reconstructed before the process can be broadened and construction resumed. The nerve structures serve as a medium for the sensorimotor intelligence, but the latter builds a series of new structures (permanent object, group of transfers, patterns of the practical intelligence, and so on); the thought processes are based on

sensori-motor action; from which they are derived, but they reconstruct into representations and concepts what was acquired in practice, before broadening considerably the range of initial structures; reflexive and abstract thought restructures initial mental operations by placing the concrete into the sphere of hypothesis and propositional or formal deduction. In the creative adult, this movement of constant construction continues [illegible] as shown, among other things, by the forms of technological and scientific thought(23).

(b) Kenneth Lovell, while carrying out several studies on developmental processes in thought among children varying widely in age, intelligence and culture, has suggested several problems which cry for solution for their solutions are of direct relevance to development of effective curricular programmes. Some of these problems are:

1. What is the role of experience(physical and mathematical) in intellectual development of children? How is it to be handled?
2. Like Head Start Schools in U.S.A., what is the long term influence or impact of early stimulation of the culturally deprived and of certain types of school educable retarded children?
3. What is the effect of variables like emotional life(fantasy), teaching and learning techniques based upon Piaget's work, culture and subculture

patterns and the restricted functioning of any schema within a given area of knowledge at one time on cognitive growth?

Lastly, he adds that lot of information is needed 'regarding the growth of more advanced concepts in mathematics and science, e.g., function and entropy'(24).

(c) Michael A.Wallach, while reviewing research on Children's Thinking, regards the contribution of the Geneva School quite monumental 'with a close blending of empirical description with theoretical speculation.' He refers to the study of P.R.Hofstaetter on The Changing Composition of Intelligence in which he has shown structural changes taking place, using a highly mathematical technique called factor analysis. He then adds:

> ... It is apparent, therefore, that the point of boundary between Thinking and Learning is, to at least some extent, arbitrary. Several other research directions may be mentioned, all concerning aspects of thinking which have yet to be extensively examined from a developmental point of view. These include fantasy and curiosity in cognitive activities, the related topic of originality, inventiveness, or creativity inn thinking; and

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> variation in aspects of thinking as related to factors of personality and motivation, to parental attitudes, and sex of the child..... Perhaps the most striking general conclusion to be drawn from the developmental information we have reviewed in this chapter is that the human's basic categories for analysing physical reality are a product of slow and laborious construction(25).

(d) E.A.Lunzer while disposing of Bryant's criticism of Piaget in the Piaget Controversy makes a few specific points requiring our urgent attention for investigating thinking. First, it is necessary to seek information about the extent to which specific gains obtained in specific settings can be generalized to wider settings. Secondly, just for the sake of novelty, one type of drill, say, number, should not be replacedby, say, drill in conservation of numbers. Thirdly, rules of thumb procedures, of course, necessary do not solve our entire educational problems for life presents quite different problems. Fourthly, the theoretical and practical educational implications of Piaget's work on thinking and learning are narrow and limited for they do not fully solve problems faced by educational psychologists and the practising classroom

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teachers. It is of interest to point out that only a small amount of variance in scholastic performance is accounted for while considering the three levels of operativity as envisaged by Piaget. Fifthly, it is necessary to investigate the relationship between thinking and operativity, range of response at the given level of operativity; and the distinction between levels of tasks and levels of children's thinking as argued by J.S.Bruner. It is quite possible that a simple logical experiment like the one used by Watson may fail to evoke formal behaviour from the graduates. He then adds:

> Piaget draws attention to an important difference between associative learning(learning facts and certain skills) and the learning which leads to a restructurization. Or, as we might say, a reprogramming of approach strategies in relation to complex tasks. But to recognize that there is a difference is not enough. What are the relations between intelligence, learning ability and the development of logical thought?.....
> At the very least, a knowledge of the changing patterns of inter-correlations among a wide variety of tasks(learning, problem solution, memory, attention, language, etc.)should offer some leads.

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In the end of course, statistical correlations are not enough. What is required is an overall model, supported by experiment, within which what we call learning, intelligence and thinking will be redefined. More than one break through is needed to achieve this. When it is achieved, Piaget will have been superseded. But not in the sense that his findings will have been shown to be supurious. Only that the perspective, broad through it is, is still too narrow and too imprecise(26).

(e) It is pertinent to consider the logical structure of any school subject. Specifically speaking, in case of science, scientific knowledge is exploding at an accelerated rate in each decade towards the closing half of the twentieth century. This, in itself, is creating lot of problems for curriculum maker at all levels of education. Perforce of circumstances, he is compelled to search for the most powerful concepts(still evolving) which build up the picture of, say, physics, in our times. This guided the very rationale of P.S.S.C. in terms of providing powerful concepts capable of transfer in wider contexts with a view to present a complete picture of physics. G.C.Finlay has aptly remarked:

The Committee has chosen to select subject matter and organize it with the intent of providing as broad and powerful a base as possible for further learning- further learning both in and beyond the classroom. Through its materials, the Committee seeks to convey those aspects of science which have the deepest meaning, the widest applicability.

The explantory systems of physics and how they are made have much more forward thrust as educational tools than the individual application and the discrete, unconnected explanation. Thus the PSSC has chosen for its subject matter the big over arching ideas of physics-those that contribute most to the contemporary physicists' views of the nature of the physical world...
The power of the big ideas is in their wide applicability, and in the unity they bring to an understanding of what may appear superficially to be unrelated phenomena..
Pedagogically this choice has virtues...
Principal among them is the acquisition of criteria by which subject matter can be selected and organized toward the coherence the subject it [illegible]

Math atics is also undergoing the same development. At this point, David P.Ausubel intervenes by suggesting the use of Advance Organizers for enhancing learning by taking the maximum advantage of the Big Ideas of Science in the form of 'subsidiary facts' concepts and generalizations subsumed under them'(28). It is implied that the 'Organizers make use of established knowledge to increase the familiarity and learn-ability of new material, and also take into account children's misconceptions about and folklore models of physical and biological causality' (27). In contrast to this, Robert Karplus has designed three different types of lessons, namely, exploratory, inventive and discovery for developing scientific concepts among elementary school children in the Science Curriculum Improvement Study Project under the influence of the Geneva School(29). J.S.Bruner has talked of Teaching Science as a Tool subject(30). Currently, Science education method specialists: A.R.Hibbs and J.R.Suchman have advocated the acquisition of general inquiry skills, appropriate attitudes about science, and training in the Heuristics of Discovery'(31). The result of all this is that the two dimensions to the content and form of science have become very active which on the very surface, appear to be conflicting. It is a very serious problem for the very basic data obtained in the context

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of new generation, projects are expected to challenge our age old educational nations because of its being entirely new, novel and exciting, pointing to radically different concepts potentially applicable to the teaching-learning process(32). To quote J.S.Bruner:

> Unbridled enthusiasm for audio-visual aids or for teaching machines as panaceas overlooks the paramount importance of what we are trying to do. A perpetual feast of the best teaching films in the world, unrelated to the other techniques, could produce bench bound passivity(32).

(f) Reference has already been made to the Revolution in Science Teaching. Lee J.Cronbach, while discussing the Psychological Issues and Recent Curriculum Reforms, says that the seniors at the college, after a long period of absence, have returned to their juniors working at schools, with a view to help them how to familiarize the youngesters with the nature of scientific or mathematical thought;

> My message has been that psychological knowledge is inadequate to answer the questions, now being posed by educational leaders. Part of the fault has been our over-confidence. We have failed

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to realize that traditional experimental designs made it impossible for us to ask vital questions. Moreover, there has been a great deficit of research on educational learning since 1920. Today, we find a happy conjuction of demand for psychological knowledge,new interest among psychologists in cognitive processes, and challenging matters to investigate(33).

In continuation, Jerome S.Bruner, indirectly hints at the problems to be investigated which in a way are more philosophical than psychological or technologycal for they reflect the type of vision that we hold for the end-products of our educational efforts. He says:

> Much of the learning in our classrooms is atmoistic and episodic; children learn one fact here, one fact there. This sort of curriculum is made up of separate units, each a task into itself. "We have now finished addition; let us how move to multiplication." I do not wish to make it seem as if our present state of education is a decline from some previous Golden Age. For I do not think there has ever been a Golden Age in American public education..... The volume of positive knowledge increases at a rapid rate. Atomizing it into facts to be filed is not likely to produce the kind of broad grasp that will

One of the principal objectives of learning is to save us from subsequent learning. When we learn something, the objective is to learn it in such a way that we get a maximum of travel out of what we have learnt. If the principle of addition has been grasped in its generic sense, it becomes unnecessary to learn multiplication, for, in principle multiplication is only repeated addition. Learning something in a generic way is like leaping over a barrier, on the other side of which is thinking. When the generic has been grasped, we are able to recognize new problems as examplars of old principles we have already mastered......

A significant aspect of the human mind is its limited capacity for dealing at any one moment with diverse arrays of information. We must,therefore, condense this information to that having general significant(34).

3- Concluding Statement:

It is evident from the above mentioned problem statements that the above mentioned basic problems in one form or another are being encountered at different levels. Both researchers and practitioners are asking a different sort of question but with the same general objective in mind. Specifically speaking, the working

teacher wishes to know how to present the subject matter of science to the youngsters with a view to develop their thinking. The curriculum builder, while insisting on the inquiry approach, wishes to know the order of subjects or parts there of to be approached respectively by him as well as by his pupils.

The subject matter specialist at the research level is engaged in finding the most powerful scientific concepts which could trigger off young Children's minds in the direction of the subject. The cognitive as well as the method specialists wish to relate the mental development of children to the most powerful scientific concepts with or without the use of appropriate first hand experiences, by determining the ' transfer value of statements of principles given to a subject, as contrasted with individually derived principles' (35). The philosophers of science wish to relate our work with fundamental purposes of human life so that no violence is meant as well as done to young learners. In a restricted frame of reference, it is a three tier problem involving research on the origin and growth of thought processes, methods of teaching(use of instructional and illustrative material also included);

contd... 31.

and the continual selection of the most powerful basic concepts relevant to teaching learning process in the wake of recent revolution in scientific knowledge. Naturally, a very broad frame of reference is needed to answer these little understood problems which can only be built up if there were already a good number of specific studies in each of the above mentioned areas which when integrated will surely succeed to illumine the very basis of human thinking. At present, it is a pious hope as the next chapter will show. The present study is an attempt in that direction(35).

SECTION B

THREE THEORETICAL STANDPOINTS.

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Introduction

Latin Poet Terence once remarked," Being human myself, I regard every thing to do with human beings as my concern"(36). It is an excellent remark applicable to human thinking, learning, adjustment and attitude. Speaking restrictedly, it can be very safely said that our knowledge about how children learn science is very little. Yet it is a fact that learning goes on in a big way among humans and, to a varying degree, in animals as well. It may be provoked by new and novel material, repeated presentation of the same in different ways, opportunities for practice and individual curiosity(37). Like Peel, E.A. Lunzer then poses several problems which need to be answered by the researchers; conditions for learning maximally, amount of practice, the nature of very learning, the contextual operation of intelligence (for example, rapidity in learning) and the nature of difficulties underlying various learning tasks (38). It is also well known that we least make use of the basic concepts drawn from the various learning theories and the well known empirical studies including action research variety in our day to day instruction(38). Even in this decade, no serious and sequential effort has been made

to select even few concepts, demonstrate & illustrate them under all possible conditions, for as many school subjects as possible, encountered at school right throughout the school(39). Research of the practical type relevant to the teaching of various school subjec including science and mathematics is little in this country(39). Even in literature, ideas lie scattered here and there which when consolidated should help us a bit in relating the mental development of children to the powerful concepts of science. It is, therefore, necessary to see the problem of human thinking in term the following eight theoretical standpoints out of whi the last three ones are of much significance in view o the scope of this study:

I. S-R Theories.

II. Gagne's Viewpoint.

III. Phenomenological Theory

IV. Factor Analytic View

V. Information Processing

VI. Gestalt School

VII. Geneva school

VIII. Accelerated Learning

1. Gestalt School

Wurzburgers were the first to investigate thou

experimentally and, in fact, developed their own method called 'systematic or experimental' introspection(40). They were not interested in problem solving as such but confined themselves to such questions as 'what is the consciousness when we are thinking of"? " Why does a subject start thinking"? They consequently considered consciousness as passive entities(25). They also did not distinguish between productive and reproductive knowledge(or thinking as the same laws applied to both). As a more fruitful and productive model appeared on the scene, the whole approach of Wurzburg school fell'like a house of cards silently and without any resistance'(40). This productive model was the Gestalt psychology whose leading figures were Wertheimer, Kohler, Koffka, Duncker and Lewin. They violently attacked the prevailing association psychology; structuralism, functionalism and behaviourism then prevailing in America; and in simpler words denied the possibility of interactions of simpler bonds developing into intelligent as well as purposive behaviour. It is a paradox that this school is deeply rooted in philosophy; and physiology which was little developed at the beginning of the present century. If we avoid the controversies, two key concepts in relation to science teaching appear in literature,these being Insight and Productive Thought.

Features of Gestalt Psychology: These are:

Perception is superior to sensation. Laws underlying perception extend not only to thinking but also to the objects of thought.

It is neither additive nor summative or either process or product. Whole is not simply the numerical aggregate of its constitutents.

Behaviour always takes place in an environment.

P-sychological processes operate in the present field which are subject to Gestalt forces; symmetry, continuity, proximity, closure and good form etc.

Psychological field is not mystic for a corresponding field functions in the brain, that is ' interaction occurs among the brain correlates of the perceptual facts in question'. These two processes are, in fact, isomorphic (parallel) which imply equality of structure, thus, making a physical physiological explanation of psychological organization.

There is least stress on memory and past experience (41).

They have emphasized the dynamic nature of the and then posed main problems underlying thinking re restrictedly speaking, problem solving or

productive thinking. Being dissatisfied with the existing approaches of traditional logic and association theory, Wertheimer posed to himself the following question and then attempted to answer it as well:-

> What occurs when, now and then, thinking really works productively? What happens when, now and then, thinking forges ahead? What is really going on in such a person? These are not easy questions to answer when solution depends upon observing such processes as they actually go on in the mind.
>
> What really takes place in such processes? What happens if one really thinks, and thinks productively? What may be the decisive features and steps? How do they come about? When the flash, the spark(49)?

He goes on to speculate about conditions,favourable and unfavourable that influence attitudes towards thinking; good or bad; and the methods of improving it. Then he poses problems for the development and improvement of thinking in a manner which have direct implications for the effective teaching of school subjects, comparable to that of 'Operational Research' or 'Museum of Defects',the two

popular key concepts in industry. He asks; "Suppose we were to make an inventory of basic operations in thinking - how would it look"? " What basically is at hand"? "Could the basic operations themselves be enlarged, improved and then be made more productive"(42)? Lastly, he tried hard to distinguish between structural and non structural solutions when he discussed some problems relating to paralellograms, sum of the angles of a polygon and summation of series which are well known in the literature. In this thought provoking discussion, it remains unclear how the non structural solution changes into a structural one for Koffa rephrases this problem again when he says," How does a problem find its solution, how does the stress set up by a question contrive to create those conditions which make the answer possible"(43)? He adds further: "The problem of the arousal of a new process is not in all cases a problem of traces" (43). The immediate cause is still shrouded in mystery for this problem has been duly recognized by Wertheimer, Duncker, Maier & Claparede(43).

Karl Duncker on Problem Solving. Particularly speaking, let us now refer to the work of Duncker on problem solving. Using problems of practical variety havir clear cut solutions, he stated his main thesis as follows:-

In the present investigation, the question is; How does the solution arise from the problem situation? In what way(s) is the solution of a problem attained? .....A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever, one cannot go from the given situation to the desired situation simply by action, then there has to be recourse to thinking.(By action we mean the performance of obvious operations), Such thinking has the task of devising some action which may mediate between the existing and the desired situations. Thus the solution of a practical problem must fulfil two demands. In the first place, its realization must bring about the goal situation; and in the second place, one must be able to arrive at it from the given situation simply through action(44).

At every moment during the course of problem solving, the direction of a solution-process depends on the psychological relief map of the problem situation, the disposability and the looseness of the elements constituting the problem. Two of his world famous problems as quoted in literature are mentioned below:

(a) The Compensated Pendulum.

You have seen a pendulum. The showness of fasteness of the pendulum depends upon its length- the distance between the point of suspension and the centre of gravity of the bob. In winter, this length decreases and the clock goes fast and vice versa in summer. But we want the clock to run with absolute accuracy. How can be this defect remedied? Lastly, we are 'only concerned with the length of the pendulum for the rest, the pendulum may have any appearance at all'.

(b) The Stomach Tumour Problem.

There is a patient suffering from an inoperable stomach tumour. Radiation at different intensities is available. The problem is to treat the tumour without destroying the healthy tissues surrounding it. What can be done(44)?

Case study approach is employed. The method of procedure is quite simple. The subject is asked to speak aloud all the ideas(both sensible and otherwise) which strike him during problem solving. Further, the subject is free to question the experimenter whenever the former

is in doubt or does not feel completely informed about the problem under attack. All the responses emitted by the subject are recorded. This dialogue continues till the problem is solved partially or fully or when the subject gives up. The following conclusions emerged from his studies;

(i) One solution is as good as any other solution so far as the 'way out' of the problem situation is concerned. What is reflected, in fact, is the degree of the acceptance of the demands of the problem. Extraneous considerations enter into the problem situation when the essential aspect of the problem is not grasped.

(ii) Duncker then distinguishes between fuctional solution and the specific solution. The functional solution may be right or wrong. It only reflects the general range of approach or even availability of ideas on a particular problem. At the specific execution of the solution stage, the problem is simply to fill in the minor details only. He then goes on to distinguish between meaningful errors and stupid errors. The former arise in the specific execution of the right idea and the latter ones

arise when the grasp on the problem is either absent or too poor. He is then able to distinguish between organic solution and mechanical solution by the type of behaviour shown by the subjects during problem solving(In the final written form of the solution, this distinction is very difficult to maintain and Duncker is aware of this difficulty). The organic solution is meaningful, less elegant, long and time consuming whereas the mechanical solution is concise and follows a set pattern. Moreover, in the case of an organic solution, one sees clearly the evidence for the analysis of the goal, analysis of the situation or conflict("where is the ground of the trouble"?) and analysis of the material. For instance, Piaget's work on number shows the concept of mechanical solution in the case of children who compute accurately without even understanding the basic ideas, a finding consistent with John Holt(45).

(iii) Generally speaking, in the case of a successful solution, each response to the problem situation is in fact the reformulation of the problem developing organically. In prospect, it is the nature of another problem(Concretization of the goal) and in retrospect,the nature of a partial solution to the problem. The

formulation of the problem more productively then implies the emergence of one or more than one functional solutions where a specific statement or a series of specific statements leads to the final form of the solution or solutions.

(iv) Cues and hints are only understood when they approach the genealogical line under development, a finding consistent with the Law of Anticipation as stated by Selz. According to it, success favours that operation which 'anticipates the sch matic anticipation of the solution' approaching fully its anticipation(46).

(v) Solutions learnt mechanically, that is, without understanding tend to be forgotten in the near future. Past experience then does not gurantee success because the very essential of the problem was not grasped then.

Productive Thought & Insight. Gestalt psychology had its origin in the field of perception and the Gestalt Laws developed here were found to be applicable to learning, thinking and thought processes. According to Gestalt psychology, 'thought was not an unaltered return of the previously learned experience', as hitherto considered(40). Even the very recall of the solution would depend upon the prevailing conditions(41).

We have already referred to structural and non structural solutions as pointed out by Wertheimer for behaviour is not blind as it is' a sensitive response to the structural relations existing in the situation as a whole"(44).Duncker and Katona explained productive thought in terms of synthetic insight and meaningful versus rote learning(47).Szekley went a step further by suggesting that the'very reorganization of knowledge is retrospective in character'(48).On further analysis, it appears that the concept of productive thought is more basic than the concept of insigt. In fact, the concept of insight can be easily hooked to productive thought for the 'pleasant Gestalt Journey' begins when one moves ahead on the basis of incomplete information,with or without' aha' experience on the way.

Insight. It is one of the main contributions of Gestalt psychology to 'problems of learning; identification and characterization of insightful behaviour and insightful transposition'. It is interesting to point out that Kohler attributed this concept of insight to animals on the basis of experiments carried out on chimpanzees during his imprisonment on the island of Tenerilic during the first world war(36). He found that, unlike a rat, chimpanzee is capable of using tools which is not an innate ability. He does it because he 'discovers them as a result of successive restructurizations of its perceptions' to meet the requirements of the problem in

which meaningful errors are partial insights on way to the complete solution of the problem. He thus rejected trial & error learning as propounded by Thorndike and in its place, 'paid attention to the immediacy of insightful solution' whose characteristics according to E.A.Lunzer are:

1. Suddenness of solution.
2. Immediacy and smoothness after solution.
3. Ability to repeat solution without error on successi-ive presentation of original problems.
4. Ability to transpose the solution to situations exhibiting the same relational or structural feathres,but in a different context(49).

Whereas Kohler showed this phenomenon in chimpanzees, Wertheimer, the father of Gestalt Psychology, demonstrated it in children who brought out successfully the structural features of the problematic situations based upon figures of equivalent areas after having undergone a few appropriate experiences but, at the same time, had not learnt Euclid(42). The opponents of this term, on the other hand, have characterized it as' mystic, mysterious, anti-scientific and accidental'(40). It is so because according to them, it is not possible to predict the moment of prediction. Consequently, according to E.A.Peel, this term has itself demanded a lot of explanation (40). There is,

however, agreement that insight occurs when there is integration of experience, a restructuring or seeing of the new relationship to the problem at hand. Provided the intelligent world existed, Duncker tried hard to distinguish between analytic insight and synthetic insight. The former corresponded to the reproductive knowledge and the latter, to the productive knowledge. It is not possible to distinguish between the two solutions on the basis of the above mentioned two sub-concepts because both understanding and inference are present in successful as well as unsuccessful solutions. This difficulty further increases, according to E.A.Peel, when Gestalt psychology does not evaluate productive thought(40). In other words, it is safe to say that insight implies more than aptness of the solution rather than the existence of high I.Q.(39). Yerkes, another animal psychologist but not a Gestalt one says, " that the conventional formula for habit formation is incomplete and that the process of trial & error is wholly inadequate as an account of anthropoid adaptations" (39). He has independently determined the characteristics of insight experimentally which are quite comprehensive and throw light on this concept as developed by Gestalt psychologists. It appears that the word ' insight' is tried to the changes in

the problem situation itself which bring about the experience of insight to the subject. Van de Geer appears to have said a last word on it when he says:

> A shift in meaning is apparent. It meant to indicate a specific inner experience, later it was regarded as a certain kind of behaviour and now it appears to be a sort of psychological principle(40).

In summary, the Gestalt Psychology, according to Irwin Slesnick, visualizes an active role for the learner in his learning process for he is not a passive entity(50). This implication is naturally linked with self-study and self-education, an excellent culminating point for any educational system any where in the world. Secondly, it discourages the acquisition of facts, concepts and principles without understanding, a positive step towards real learning and knowledge. Thirdly, it stresses divergent thinking in the phraseology of Guilford, that is going for beyond the starting point in one's thinking by setting up all sorts of hypotheses (open hypotheses) and testing them against the given data, the demands of the problem or setting up control experiments with a view to exclude irrelevant variables. These new scientific concepts or insights,

according to Irwin Slesnick are gained through a 'series of acts of discovery, however, small these steps may be.'(50).

2. The Geneva School:

Educational ideas like scientific ideas do not develop in vacuum for they have their past in educational principles 'rooted in the wisdom of the ages', dating back to the ancient Greek thinkers like Socrates & Plato. Since then, the ideas of many great thinkers representing different disciplines have been woven into the fabric of current educational philosophy and practice' (51). Piaget drinks heavily from this philosophical spring and even pays back his ancestral debt abundantly in his life time to the moderns and the futurists for it is impossible to imagine today any study on cognition without reference to his work. He presents some sort of thought provoking synthesis of various theories. In his thinking, he has been influenced by Plato's rationalist tradition, Kant's doctrine of mental categories, Bergson's notion of perceptual change, work of Gestalt psychologists, use of logic for inter-pretation of thinking (classes, relations, grouping, reversible and equilibrium) and several individual personalities past & present of his country. A few to mention are: Calvin, Rousseau, Pestalozzi, Claparede, Binswanger, Bleuler, Rorschach, Meili, Jung and Sechehaye(51).

On the top of it, his own subject: Biology has coloured his entire work when he stated:

> Development is continuous not only with the individual but throughout all evolutionary levels. From the biological to the social to the intellectual level, the unity of nature is preserved. The functioning of the loveliest mollusk is based on the same fundamental processes as that of an Einstein(52).

So the contribution of Piaget and his coworkers is monumental. This is despite the fact that his work did not evoke much interest for long. One of the reasons for this poor appreciation was that Piaget is and has been a difficult author to read and understand. But the last twelve years have brought a complete reversal in researcher's attitude toward Piaget. The reason for this is that much of recent research has been geared to verify and test Piaget's basic ideas. Now, according to J.G.Wallace, he can be ' fairly said to bestride the field of contemporary ontogenetic studies like a colossus'(53). Piaget chooses problems for investigation from the area of cognition without considering at the same time any other outside variables like intelligence, socio-economic status,

rural and urban differences, personality traits and even motivation. He takes each piece and interprets it from all possible viewpoints (including historical and philosophical) and then gives his own view point. And in this process, he discards all the alternative interpretations considered earlier. It hardly matters for him even if he has to go a long way, according to J.H.Flavell, in explaining his view-point even at the cost of limited data collected empirically for the purpose(54).

Piaget acknowledges his debt to Gestalt Psychology in his thinking. A mention has already been made that Gestalt psychology is itself quite rich in ideas for teaching science effectively. But Piaget goes a step further when he says that his schema are ' more dynamic and modifiable structural units than are the Gestalts' (52,54). They are characterized by mobility, transposability,generalizability, elasticity, self-modifiability to fit new data, built-in activity; and lastly, they undergo evolution through corrective contacts. Inferior schemata then become superior ones which are, comparatively speaking, more adequate to reality adaptation. There is no place of insight because the complex schemata arise or evolve from the simpler ones already formed. To put in simple words,

unlike a Gestalt, schema has a past history(continuity)which has its own laws of development. It may be therefore inferred from the above, that Piaget does not reject Gestalt psychology in toto but on the other hand, he makes it more mobile and consequently replaces its ' apriority with a genetic relativity' (54).

Method of Procedure. Piaget does not use standardized procedures (perception excluded). He chooses methods and techniques reflectively for effective exploration relative to the phenomenon under study. He develops his own concepts which are at times misunderstood, misquoted and found to suffer not only from defects but also he is found to apply them differently, i.e., their meanings appear to change depending upon the period of his work. Difficulties of the readers increase when he does not at all explain his concepts sufficiently well but takes them for granted in his abstract reasoning. At the same time, while sticking to his field, he evaluates critically the findings of others and accepts criticism in turn(49,54).

Piaget's approach is elastic and flexible. His method is clinical which demands both' imagination and critical sense' for a great care is taken in not imposing the experimenter's point of view on the child. Further, Piaget is able to establish a very good rapport with his subjects,

In one of his experiments, he proceeded somewhat as follows:-

> Piaget : What am I doing ?
>
> Pupil : You are clapping.
>
> Piaget : What am I doing ?
>
> Pupil : You are slapping (55).

Then Piaget presents the problem. He thus succeeds very well in giving us the inside view of what happens when children think. He does this by observing his subjects in informal situations, that is, under natural conditions, questioning them verbally about their every day concepts round the natural phenomena; and investigates their thinking through his highly ingenious experimental materials and physical experiments. He then classifies their responses into stages and discusses the main distinguishing features of each stage; and how it is linked with both its predecessor and successor stages. He also reports analysis of frequencies of responses and dispersion by ages. He then links these stages to his highly mathematical and abstract logical models. He hardly computes the conventional sort of statistical measures. He hardly uses tests of significance. This naturally publicizes a false impression that Piaget does not have any grounding in statistics and mathematics. To such critics, he has given one apt reply:

The object of these studies, initially, was not

to establish a scale of development and to obtain precise determinations of age as regards stages. It was a question of trying to understand the intellectual mechanism used in the solution of problems and of determining the mechanism of reasoning. For that we used a method which is not standardized , a clinical method, a method of free conversation with the child....That is why, personally I am always very suspecious of statistics on our results. Not that I dislike statistics; I worked on biometrics enthusiastically when I was a zoologist, but to make statistical tables on children when each was questioned differently appears to me very much open to criticism as regards the results of the dispersion(56).

He has his own reasons for selecting and developing these unconventional techniques. One should not miss the point that Piaget aims at investigating and finding out as much as he can(may it be at its worst considered a sort of exploration) successive cognitive structures in the whole

process of ontogenetic development among normal children. Therefore, researchers on Piaget have simply to learn to live with them(techniques) for the essence of his critical methods is to' separate the wheat from the tares and to keep every answer in its mental context, the context may be one of reflection or of spontaneous belief, of play, or of prattle, of effort and interest, or of fatigue'(57).

It is just recently that Piaget has expounded his eclectic methods of research and theory construction. In these, he employs two essential approaches which have much in common with those applied to nuclear sciences. These are a detailed analysis, in order, of an investigation based upon cause and effect constituting a net-work characterized by hierarchical relationships and combined connections and the consequent 'analysis of implications by considering both the field as a whole and the co-ordination of its parts, in mathematics, this is comparable to the group, and in logic, to the propositional operation.' Empirical investigations and the inductive mode of reasoning are akin to the first approach, while reasoning by logic and constructing hypotheses by deduction is similar to be second(50). Piaget believes and stresses that symbolic logic like statistical techniques is a productive research tool in psychology as well. One of his colleagues, Inhelder says:

The use of such tools in no way implies that

the psychologist has succumbed to logicism, that is, has decided in advance that the real thought of the child should conform to the laws which govern logical and mathematical structures. Only the facts can decide whether or not it does so conform.....These models represent the ideal system of all possible operations, while actual thought makes but one choice amongst them. More than twenty years of research have shown that cognitive development approximate these models without attaining them completely(59).

Psycho-Logic. Just as mathematical physics helps the physicist to interpret experimental findings in physics, similarly, Piaget constructs his own logic to investigate and interpret intellectual operations. For the last thirty years or so, Piaget has been using successfully the various techniques of symbolic logic for uncovering the intellectual behaviour of young children. It won't be out of place to mention here that Piaget is not the first to recognize the importance of logic to test inferences based upon observations. He got this idea from the studies of Kulpe and his students at the Wurzburg school in Germany. Their studies indicated the accessory role of images (not essential as associationists would imply),

possibility of reporting the intellectual feelings and attitudes and thought consisting of anticipatory schemata,intention, rules and relationships. Apart from borrowing models such as those of Klein and Bourbaki from modern mathematics, Piaget himself has developed one of his own called' groupements' which are comparable to semi lattices (59). Inhelder has suggested the use of another weaker model which makes use of Boolean algebra. The adequacy of these logical models has been questioned by many critics like Issac (1951), Parsons(1960),Braine(1962) and even Bruner (equilibrium as a transition rule). Lovell's remark that Piaget would have produced a different child,had he had no training in Biology: and certain branches of mathematics had not developed as much as we find them developed in our times (60). It is quite probable then that he may not have produced any child at all as our knowledge is as best as the prevailing conditions allow. And as Wallace says, ' his early training in Zoology, together with his increasing interest in recent years in symbolic logic and the mathematics of groups and sets, have clearly influenced his account of the genetic structures of the child's minds' (53). To conclude with Bruner, there appears to be a potential dynamism in Piaget's system which could diminish some of

its angularities. He says;

> ....What is plain is that the adolescent differs from the child not simply in that he used a propositional calculus that deals with possibilities rather than merely with actualities, but rather that he is forced to deal with possibility by the nature of tasks that he undertakes and by the nature of the unfolding and development of his drives and the social connections required for fulfilling them. It is not an equilibrium which keeps him back in these concrete operational stage and not a new equilibrium that brings him forward. It is the vicissitude of coping with demands- internal and external. The growing enterprise, that is, an adolescent is now operating on a different programme. Logical structures develop a support the new forms of commerce with the world. It is just as plainly the case that the pre-operational child, protected by parents, need not manipulate the world of objects unassisted until the pressure for independence is placed upon him at which time concrete operations emerge. So the concretely operational child need not manipulate the world of potentiality (save on the fantasy

level) until the pressure is put on him, at which point propositionalism begins to mark his thinking. It is no surprise, then, that children of intellectually under-privileged families or of manual workers tend to be less challenged in terms of a sense of possibilities and do not develop what we commonly speak of as an abstract gift(61).

Through the use of his symbolic logic, Piaget is able to discuss the properties of thinking(processes) at various age-levels in terms of what operations children within the age group are capable and incapable of performing. He gives reasons why a particular problem (say Shobha is fairer than Rukmani and Shobha is darker than Shubha, who is the darkest of the three?) cannot be solved by the children within the age group 7-11 years. He said that the thinking of the children is concrete and so they cannot react to the absent situation. Logical operations available to them are not sufficiently generalized: and consequently they can tackle only those problems which are presented to them concretely. To put it in other words, they have not yet evolved a corresponding cognitive structure. When this cognitive structure is present, children try hard to tackle the problem systematically. Trial and error is gradually reduced to the minimum.

Concept of Operations: Prof. Bridgman in U.S.A. was the first to champion that operationalism provides a real meeting ground for psychology and logic. As is known, operations play an important part in logic which is based on an abstract algebra and is made up of symbolic manipulations. Here, operations are considered real psychological activities on which our whole effective knowledge is based. Piaget has therefore attempted to develop a psychological theory of operations which links psychology to logic. Roughly speaking, operation is a means for ' mentally transforming data about the real world', so that they can be later on organized and used selectively in problem solving. Operation is internalized and reversible and thus distinguishes itself from a simple action or goal directed behaviour. Consider Piaget's definition of operations:

> Psychologically, operations are actions which are internalizable, reversible, and co-ordinated into system characterised by laws which apply to the system as a whole. They are actions since they are carried out on objects before being performed on symbols. They are internalizable, since they can

also be carried out in thought without losing their original character of actions. They are reversible as against simple actions which are irreversible. In this way, the operation of combining can be inverted immediately into the operation of dissociation.....Finally, since operations do not exist in isolation, they are connected in the form of structures wholes(62).

These operations evolve gradually and one can distinguish four main stages in their development, these being the Sensori Motor, Preoperational, Concrete and Formal which cover period from birth to maturity(59).

Basic Ideas. It is difficult to summarize the basic ideas of Jean Piaget for he and his coworkers have contributed immensely to the whole field of psychology; perception, reasoning, intelligence, dreams, moral development, space, time, play, thinking from early childhood to late adolescence and other varied problem areas. It is interesting to note that he has devised highly theoretical, abstract and imaginative frame of reference which have won world wide fame; and are admired highly by researchers on cognitive development with little concern to the theoretical frame. In this

context even Flavell, the best American Publicity Officer, Piaget so far has, is no exception. It is then least surprising that he evokes extreme comments on his work. James J.Gallagher has attempted the following five major themes like conceptual schemes in science running through Piaget's work on the ' development of intelligence as part of the more general process of biological development'. These are:-

(a) Continuous and progressive changes take place in the structures of behaviour and thought in the developing child.

(b) Successive structures made their appearance in a fixed order.

(c) The nature of accommodation(adaptive change to outer circumstances) suggests that the rate of development is, to a considerable degree, a function of the child's encounters with his environment.

(d) Thought processes are conceived to originate through a process of internalizing actions. Intelligence increases as thought processes are loosened from their bases in perception and action & thereby become reversible, transitive, associative, and so on.

(e) A close relationship exists between thought processes and properties of logic(63).

These are very broad as well as grand hypotheses. Let us, therefore, consider some of the basic ideas of Piaget with special reference to the teaching and learning of science.

(A) There is a constant interaction between the organism and the environment. It is out of this encounter that the intellectual structures are born. Piaget, here, introduces two basic invariants of functioning, namely, organization and adaptation which are not only inseparable from each other but also are 'two complementary processes of a single mechanism, the first being the internal aspect of the cycle of which the adaptation constitutes the external aspect'(64). This dual functional invariant of organization and adaptation is expressed by the 'accord of thought with things and the accord of thought with itself'(64). In other words, thought adapts itself to things and gets organized to structure things in turn(64). In case of adaptation, there are two interrelated components, namely, assimilation and accommodation. These are two fundamental processes, the former refers to the absorption and integration of new experiences with the existing schemata and the latter refers to the modification of schemata as the result of the new

experiences. It may be mentioned here that adaptation is a unitary event and so assimilation and accommodation are merely abstract concepts drawn from this unitary reality which are inseparable, indissociable and simultaneous as they operate in a living cognition-' intellectual acts alwa always presuppose each in some measure'. This is something like the concept of 'epignesis', a term borrowed from zoology where the ' function remains the same and the structure changes'(24).) While expounding Piaget's basic ideas, Maier says:

> .... Experiences are taken in only as far as the individual himself can preserve and consolidate them in terms of his own subjective experience. Thus, the individual experiences an event as he conceives it. Accommodation is directly converse to assimilation, and represents the impact of the actual environment. To accommodate is to conceive and to incorporate the environmental experience as it truly is. For instance, a loud noise of a door falling shut unexpectedly as assimilated according to its impact upon the individual hearing it; the nature of the noise experienced is determined by the way the individual interprets it. However, the individual also, in varying degrees, adapts to the

noise for what it actually represented: that is,he accommodates the experience. Thus,both processes always act together. They are interlocked and simultaneously involve conflicting forces between opposite poles; that is, assimilation is always balanced by the force of accommodation,while accommodation is possible only with the function of assimilation. An environmental object is never experienced unless it has a personal, assimilative impact. Piaget stresses that an object can never exist unto itself,it always involves assimilation and accommodation on the part of the experience. To repeat, processes of both assimilation and accommodation provide complementary,but opposing pulls. A pull to think to feel and to act as previously experienced is challenged by a pull to think, to feel, and to act according to the realistic demands of the new situation. Although Piaget's theory is built upon these biological models of homeostasis, he warns us as recently as 1953, " We describe behaviour in physiologic or behaviouristic terms. We describe in toto, but we do not know the underlying processes(59.).

Flavell further elucidates:

> In summary, the functional characteristics of the assimilatory and accomodatory mechanisms are such that the possibility of cognitive change is insured, but the magnitude of any given change is always limited. The organism adapts repeatedly, and each adaptation necessarily paves the way for its successor. Structures are not infinitely modifiable, however, and not everything which is potentially assimilable can in fact be assimilated by organism A at point X in his development. On the contrary, the subject can incorporate only those components of reality which its on going structure can assimilate without drastic change(66).

Lastly, in this interaction, it is not possible to find the proportionate contribution either of environment or that of organism to the total develorment. While surveying the evidence for an against the predetermined development, Hunt supports the view that 'analysis of variance model in understanding this mutual interaction is meaningless'(67).

B. It will not be inappropriate, if we elucidate some of his ideas withthe help of Kelvin scale, which is usually mentioned in physics textbooks(65). This is an

open-ended scale in which both the highest and lowest temperatures are left unfixed. It is quite difficult to place a restriction on the highest temperature, that is, maximally possible and in regard to the other, scientists get into difficulties when they try hard to obtain the lowest temperature(absolute zero) in the laboratory. Except these two limitations, this scale is quite useful to the physicists. It is possible to visualize the same thing for this mutual encounter (inter-action) between the organism and the environment out of which intellectual structures evolve. The beginningof this mutual interaction is difficult to fix due to our inadequate knowledge on the beginning of life and its mysterious reproduction; and added to this is the past history of mankind itself. Similarly difficulties arise when we attempt to fix the other end of the scale, the main difficulty being the very evolutionary nature of the knowledge itself accelerated in our times with time dimensions held in posterity. Piaget then attempts in a high way how scientific and mathematical concepts develop on this continuum. The main features of this scale are now mentioned below:-

(a) When taken in isolation, it is independent of heredity or individual experience. It depends upon both

for only then the human mind is able to create new and never novelties.

(b) On this scale, there are four main stages covering the approximate periods of 0-2 years, 2-7 years, 7-11 years and 11-15 years called the sensorimotor development stage, preoperational stage, concrete stage and the formal stage. Each stage grows horizontally as well as vertically.

(c) Each stage takes time to form and attain equilibrium. Each stage thus formed and attained is incorporated into the succeeding stage. Thus the succeeding stage incorporates the gains of the preceding stage. These stages follow each other in a fixed order for the majority of the normal pupils in which the specified age ranges can very from culture to culture. Thus, there is no rigidity regarding the age ranges. Further, it has been seen by Inhelder on the basis of longitudinal studies that intellectual development appears to be slightly accelerated.

(d) Individual differences at a particular stage are disregarded and similarly the specific differences arising due to the specific situations or experiences are disregarded but Piaget concerns himself with the sequence of development of child's thought. Majority of the children pass through these stages invariably.

e) Piaget describes cognitive development in terms of stages, which as such do not clarify anything except logical steps obtained on a particular problematic situation. Piaget goes ahead and investigates further the structure of these concepts(stages) with the help of symbolic logic. It is this work which he substantiates mathematically that gives his work a superb distinction.

f) With the help of his symbolic logic, he distinguishes among the availability of various logical operations at various age levels. In fact, he pinpoints the strengths and weaknesses of the thinking processes at various age levels and appears to give convincing reasons why the children behave as they do in his experimental tasks. These findings, he generalizes for all children in his highly abstract theoretical frame of reference which is deeply rooted in epistemology. Some of the distinctions stage-wise are:

(i) At the first stage, child lives in his own practical world and he explores various possibilities for his activities. He does not develop self-knowledge and self-consciousness about himself. He lacks language and therefore mainly performs overt activities.

(ii) At the second stage, his thinking is governed by the perceptual considerations of the situations. He makes the judgement as he sees the situation. He cannot resolve his conflicting statements.

(iii) All verbal thought is not formal. It may have in it a situation which is in fact concrete. So a formal problem may be solved concretely.

(iv) At the third stage, the subject is tied to the concrete situation or the empirical data. He criticizes data and brings extraneous considerations into the problem situation. He understands the content of the problem but fails to appreciate the form of the argument. At the fourth stage, on the other hand, possibility dominates and reality becomes secondary.

(v) Combinativity, reversibility, associativity and identity, etc., available at the concrete stage are shown to be generalized at the formal stage. This explains the emergence of operational schemata like combinational, proportional, mechanical equilibria, correlations and probabilities, etc., at the beginning of the fourth stage.

Piaget formulates the properties of these thinking processes available both at the concrete stage and the form-al stage in such a way as to include both, that is, their 'mobile equilibrium and their ontogenetic formation'.

(g) It is then easy to see the point that all thought is not formal. It may have in it a situation which is in fact concrete. So a formal problem may be solved concretely.

(h) Piaget analyses thought activities(interiorization of activities) in terms of groups or systems of operations which are relational and posses the following attributes:

a. Composition: Any two operations can be combined to produce a new operation.
b. Reversibility(inversion): Two operations combine which can be separated again. One can return to the starting point.
c. Associativity: The same operation may be obtained by combining individual operations in different ways.
d. Identity: Combining an operation with its inverse which annuls it.
e. Technology: It has a special meaning here. Repeating a logical operation only gives repetition or tautology: 3+3=3 because 3 is 3 (68).

The above are simple structures(which Piaget calls Elementary Groupements) which are available to the children at the concrete stage. These are, definitely, limited in scope when compared to lattices or to the groups characterizing propositional operations or the operations of classes and relations in their most general form', for example, Boolean Algebra. These have not yet acquired a complete combinatorial character. This in fact evolves at the formal stage and is called the groupement of the second order which is more comprehensible and general and corresponds to later mental structures. To put in simple words, there is a higher degree of reversibility at the formal stage as compared to the concrete stage. Negation (inversion) and ~~resi~~reciprocity,the two forms of reversibility get united at the formal stage in a complete operational system which was not the case earlier. At the same time, they also' correspond to the model co-ordinated transformations which are'fundamental in thought'. They are ' the operation(identity), its inverse(negation), the reciprocal of the original operation and its inverse (reciprocity) and finally the negation of this reciprocal (correlate)'. Piaget then says:

..... the construction of propositional operation is accompanied by a series of changes in the subject's

capacity to perform operations. The different schemata which he acquires are shown to imply not merely isolated propositional operations, but the structured wholes themselves (the lattice and group INRC) which the propositional operations exemplify. The structured whole, considered as the form of equilibrium of fundamental psychological importance, which is why the logical (algebraic) analysis or such structures gives the psychologist an indispensable instrument of explanation and prediction(69).

It is no wonder then that the children at the formal stage are in a position to obtain experimental proofs, find methods of discovery and develop insight into the nature of proof. They acquire operational abilities(towards the end of this stage) which make possible the undertaking of first class constructive activities in the development of scientific and mathematical knowledge.

Lastly, the process does not stop here. It continues still further. An equilibrium at a much higher level is obtained (say in case of a mature scientist) which has a link with its predecessor stage. The scale thus tends to be open-ended for the simple reason that the human mind, according to Piaget, goes on creating exciting novelties over the years(56).

The Elucidation of Stages. Let us now refer to the formal period which begins at about 11 years, reaches equilibrium at about fifteen years and finally leads on to adult logic. In this period, they learn to handle increasing-ly more and more complex logical operations which belong to the calculus of operations. They have the potentiality to perform all those logical operations which are employed by the research scientists, mathematicians, philosophers, historians and even literary critics in their works. To concretize, the adolescent pupils develop the ability to reason by hypotheses based on a logic of all possible combinations, they can deduce their implications, test and verify them. They do not criticize data but appear to accept the hypothetical data even though it may be wrong(suppose the donkey has two horns!) Their thinking is no longer tied to the real(concrete)situation. They imagine and consider all sorts of hypotheses and possibilities Reality which dominated thinking at the concrete stage is now subordinated to possibility at the formal stage. Further, they test their hypotheses by setting up control experiments and even they go to the extent of finding empirical and mathematical proofs for their observations. One sees at this stage, the emergency of systematic approach where there was earlier, largely, speaking,

a cognitive random behaviour. This is so because at this stage, they seriously look into contradictions,and flaws in reasoning and successfully tackle the whole problematic situation by considering even its basic premises,if judged necessary. The reason for this is that' there is a new means of generalization and differentiation especially applicable to the eventual integration hitherto 'uintegrated and undifferentiated structured whole'. Assimilation and accommodation obtain a comparatively higher equilibrium in this period by' integrating into unconscious and spontaneously carried out processes of human fuctioning(69).

The construction of propositions is not the only distinguishing characteristic of this period. New operational schemata (apparently unrelated to each other at the beginning) appear at about 11 + . These operational schemata are: Combinatorial operations in general (combination, permutations, aggregations); proportion(large number of different kinds of experiments dealing with motion, geometrical relations, probabilities as a function of the law of large numbers, and weight and distance relationships on the two arms of a balance); mechanical equilibrium and others relating to probabilities, correlations and multiplicative compensations. According to Piaget, the gains of this formal period are:

.. This fourth period therefore includes two

important acquisitions. Firstly, the logic of propositions, which is both a formal structure holding independently of content and a general structure coordinating the various logical operations into a single system. Secondly a series of operational schemata which have no apparent connection with each other nor with the logic of propositions.

...Justifies the following conclusion: the construction of propositional operations is accompanied by a series of changes in the subject's capacity to perform operations. The different schemata which he acquires are shown to imply not merely isolated propositional operations, but the structured wholes themselves (the lattice and the group INRC) which the propositional operations exemplify. The structured whole, considered as the form of equilibrium of the subject's operational behaviour, is therefore of
f fundamental psychological importance, which is why the logical (algebraic) analysis of such structures give the psychologist an indispensable instrument of explanation and prediction(71).

It is quite possible for the adolescent pupil to scover quite a few physical laws, for example, law of

inertia himself unaided. Why? Because earlier,the small child has 'touched, smelt, felt, dug, and climbed'. Now he is building up on this experience by ' pouring, testing, and experimenting' with a view to find sense in the world around him through self discovery(52). This shows that at this stage, new thinking skills begin to appear for he is beginning to commit himself to possibilities rather than to realities. He does not now hesitate to invert reality and possibilities. He can separate himself from the problematic situation and thus have a look at the phenomenon at a distance. To illustrate the above mentioned example on the law of inertia, he rolls balls of different sizes on a smooth surface. He finds that, whatever may be the smoothness of the surface, each ball stops after some time or over a certain distance. His reason now will not be the force applied to the ball but actually the resistance offered by the surface over which the ball rolls. It is a new variable for the nature of the surface is a factor which is outside the following variable, namely,(i) the force with which the ball is thrown, (ii) the size of the ball and(iii) the nature of the ball. This is not true only for the law of inertia. Other physical principles and laws not yet taught at school can also be discovered by the adolescent pupils of

average intelligence, some examples being the laws of reflection, Archimedes ' principle, real depth divided by apparent depth equaling refractive index, law of lever and f x D= 100 when focal length is expressed in cms. and D in dioptres(70,72). The can deduce the consequences of their tentative statements, or trial ideas for testing and verification.

There is a distinct difference between the concrete and the formal stage. At the former stage, all intellectual efforts expanded and intensified on a horizontal plane. Thinking was tied to the concrete situation and was verified or even tested within the context of the experimental situation. But, at adolescence, thinking goes beyond the immediate present and attempts are made by the adolescent pupils to establish as many vertical relationships as possible. Notions, ideas and concepts are formed which belong to the past, present and future. All sorts of hypotheses and possibilities are considered and their implications deduced and tested for relevance or irrelevance. Minute details are not at all ignored. At about the end of this period, the adolescent pupils manifest maturity of cognitive thought for they can use symbols in their operational thinking. In short, they think by applying symbols of thinking or to put in other words, they develop

concepts of concepts, a sort of second and third order reflection. While rolling balls on an inclined plane, B. Inhelder noticed a progressive change in their attitudes toward the problem solving task which became gradually objective with age. To illustrate, five to seven year olds failed to record the experiments, to reproduce them and to manifest the objective attitude. They were, in fact, overwhelmed by the situation for they were only interested that they could do to set the balls in motion. Seven to elevent year olds comparatively showed a more objective attitude for they made measurements and comparisons. Even then, they failed to discover the underlying principle. But for the adolescent pupils, the very problematic situation itself provoked them to think and' attempt at deduction and verification of hypotheses'. Why. it challenged them to interpret facts and thereby interpretations themselves became an integral part of the intellectual reconstruction. Here, E.M.Churchill then quotes Isaac Nathan who has explored at depth the educational implications of Piaget's theory:

> There are certain basic concepts which pervade and largely control the whole structure of our ordinary adult thought. Chief among these are the notions of Space and time, reality and all causation; number,

order, measure, shape and size; motion, speed, force and energy and the ideas of the fundamental logical relations, like those of whole and part, classes, class-hierarchies and their members, and implication. Most of us, of course, would not be able, and would not feel called upon to try to formulate these concepts in strict intellectual terms. But they function in all of us, and function in a highly organized and structured way and it is they that provide the coherent framework of our normal thought world through which we order all the succession of impressions, happenings and experiences which flow in upon us.

Children pick up most of these words, or words connected with them, quite soon and learn to use them in the right situation. This leads to assume, very naturally, that they have the corresponding ideas, at least, in a simple and elementary form. But, here according to Piaget's findings, we are in the main quite wrong.

Thus we end up with a tremendous contrast, above all in the early years of the child, between the onward show of his use of language and the inward reality of the actual level of organization and cohersion of his thought. The basic organizing

concepts are to all appearance not there yet, and thus have not yet done their work. Hence, beneath the surface, the world of flux to which all Piaget's experiments with children of four to six so eloquently testify. Towards seven to eight, as we have seen, the contrast lessons; the organizing concepts are starting to take shape and their work begins to show. Yet it is only at eleven to fourteen that, in the average child, the contrast really disappears. The inward psychological reality joins up with the facade and Piaget's soundings bring out everywhere, just the same kind of responses as any of us adults might give. The child now lives in the same functional thought world as we do(74).

Nathan Isaac then asks: in the light of the above, what is the real status of the so-called progressive education from the nursery education upwards? Can teacher intervene effectively when intellectual development is an inward affair? Does it mean that the progressive should emphasize and concentrate on the social, aesthetic or the dramatic aspect of the child's personality? Piaget admits that these conditions of communal life are quite conducive to the intellectual development. These disturbing questions perforce arise if we accept Piaget's findings in toto. [illegible] facts, on the other side, are also too real

and massive and can't be ignored altogether. A necessity therefore arises, to correct or supplement these facts in a comprehensive psychological frame of reference, which may give us rich educational harvest. To quote Hyde:

> There is scope for all, the clinician can study the abnormal functioning of the structure, the educationist the effects of training on its growth, the sociologist, the effects of environment and others, modifications due to individual differences. The body of knowledge about children that may eventually result from his work, directly or indirectly is incalculable(75).

3. Accelerated Learning.

It is characteristic of our times that as soon as we understand a process we ask ourselves the question whether we can accelerate that process or not. We do not have a definite answer to this question. However, let us consider here the views of some well known psychologists.

(a) Vygotsky's View. Piaget leaves us wondering about the educational implications of his work. Vygotsky goes a step further by saying somewhat as follows.

According to him, ' instruction precedes development' (76). He, therefore, analyses intellectual development as a function of instruction explicitly. For him, concepts do not exist in isolation like ' peas in a bag'. Each concept is a ' measure of generality' and they interact with each other. Each concept fits in a certain hierarchy where higher concepts throw light on lower concepts, for example, algebraic concepts throw light on arithmetic concepts. Further, he distinguishes between two types of concepts, namely, everyday concepts(spontaneous concepts) and scientific concepts (non-spontaneous). They develop in opposite directions but it is the instruction which is the main source of child's ideas; which corrects, informs and develops his knowledge. Instruction is not something external but is seen to be integrated closely with development. So planned instruction can accelerate mental development(cognitive functions). We should then aim at the ' ripening of such functions'. Piaget and Vygotsky along with the concept of ' productive thought' thrown in from Gestalt psychology it appears, present an integrated viewpoint to the teachers for teaching science effectively(70).

(b) Z.P. Diene's View. His work is on the concepts of abstraction and generalization but with this limitation that he has studied the attainment of specific mathematical

concepts in depth. He then in his work distinguishes between the constructive thinker and the analytic thinker. The former takes an overall view of the goal, works intuitively towards it, does not concern himself with the details in the beginning but may attend to them later on. Such children, according to him, manifest constructive thought and are at the concrete stage of their mental development. On the other hand, the analytic thinker progresses towards the goal(which is undefined in the beginning) consciously step by step as demanded by the ' logical requirements within the system'. Children at the formal stage of development exhibit analytic thinking. The emergence of the analytic thought becomes highly probable when constructive thought has already been well developed. There may be certain cases when poor constructive thinkers may manifest analytic thinking. In that case, one can be pretty sure that they have manifested ' shadow actions without any logical significance' in the absence of any (developed) insight into the logical sequence of various events. He then emphasizes that majority of children need a lot of constructive activities before we can expect them to develop analytic understanding. He has investigated and illustrated his ideas with the help of his specially com

constructed (for the purpose) multibase arithmetic base and algebraic experiences material. He has then formulated four principles of conceptual learning, these being the dynamic principles, the perceptual variability principle, the mathematical variability principle and the constructivity principle. Our gains will be immense if we classify the whole science syllabus (also true of some other school subjects) at these four levels in the form of learning situations to be gradually presented at various age levels. Accelerated scientific and mathematical thinking may then result(77).

(c) Advances in knowledge take place when assumptions underlying thought processes (as understood) are questioned. For example, J.S.Bruner, Benjamin Bloom and J.McV. Hunt believe

> That an individual's achievement in life depends very largely on what he has been helped to learn before the age of four, for that is when human intelligence grows most rapidly and the roots of intellectual curiosity are laid. They also believe that millions of children are being irreparably damaged because they do not learn enough during this critical period. The result of an unplanned intellectual diet in the early years-- for middle class children-- may be a loss of brilliance, a blunted and less interesting life, smaller contribution to society. But for the children of poverty, the

consequence is nearly always disaster- a preordained failure in school and adult life(78).

Convinced by the above statement, two psychologists (they appear to be mad) Bereiter and Engelmann at the Institute for Research on Exceptional Children of the University of Illinois in Urbana are ' operating an intellectual pressure cooker'. They have rejected the usual philosophy considered progressive in the play-oriented nursery schools. On the other hand, they' concentrate fiercely on a few areas and drill the children like Marines for two hours a day'. Consider their approach in a mathematics lesson with four pupils, two boys and two girls:

> It is time to think about...work! he began fairly shouting. Are you ready for tough stuff? On the blackboard, he wrote 8 + 3 = ? Immediately the children started to roar, ' Eight plus zero equals eight, eight plus one equals nine, eight plus two equals ten, eight plus three equals eleven and the sums like 15 + a = 18 and 7- b = 2. It looks like algebra for the four-year-olds(78).

Very soon, these disadvantaged four-year-olds are ~le to 'unpack' or extract meanings from the statements. They

can speak in sentences. The students get an experience of success because the educational programme(in a very narrow sense) is geared to their capacities and capabilities. Teachers have faith and confidence in their children and,in turn, children have faith and confidence in their teachers and these arise in the very process of work from deep involvement and commitment in a common task. Regarding this project, J.McV. Hunt says:

> There is evidence of more changes in Bereiter's school than in any other I have seen. When he set up his class last year, the children tested 'under-age-three' on the Illinois Test of Psycholinguistic Abilities. They did not talk to each other at all except in single words and grunts. In each of two-three-month periods of this school, they gained about one year of psycholinguistic ability on the tests (78).

(d) In England, Wall has drawn pointedly the attention of the teachers to' distinguish between the logical structure of a subject, process or technique, and the psychological mode in which it is taught'. If a teacher presents a notion, action or technique concretely and is found of interest and immediate value by the child, it is quite possible for the

child to acquire it at an earlier age than hither-to considered than 'if it is unrelated to his interests and presented in a symbolic, abstract or generalized way'(79). The reason for this is that even content remaining more or less the same, the psychological processes involved are different(79).

Hyram has pointed out that children's school work improved when they were trained in logical operations(80). Morf has also found that children were induced to learn 'certain operations of class inclusions by emplying a method involving direct training on the operations of logical multiplication'(81). But investigations of Lovell and Ogilvie and Dowedell do not favour the acceleration of concept formation when training in logical operations is given to the students(81). We can, however, safely conclude that a very potential and fruitful area of research awaits invasion by the educational psychologists, and teachers in particulars.

(e) J.G.Wallace in his recent book on Stages and Transition in conceptual Development, has also referred at depth to the problems underlying such studies, the problems being philosophical, psychological and technical(85). There are problems for the practitioners as well when not only sub-normal but also normal pupils fail to form Schemata which they ought to have in their normal course of development. For

example, Elkind found that about 58 per cent of the American Adolescents in the age group 12-18 year olds failed to conserve volume(83). Hence, there is a scope for improvement here because, when left to themselves, they cannot perform this job themselves efficiently. " The end in view is, then, the production of adults possessing a comprehensive range of cognitive tools, as Flavell and Wohlwill have put it ' not at first but at last, not the fustest but with the mostest'(84). In such studies, what would be our gains for children? According to Wholwill, these may be ' in a particular response a group of particular responses, a more general notion' similar to operation as defined by Piaget(84). Secondly, is the process entirely new in contrast to the process normally developing one? Examining the problem from varied view points, J.G.Wallace summarizes the situations as follows:-

> .. a definitive answer to the question of the nature of the relationship between the processes evoked by training sequences and those which figure in 'normal' development is still a considerable way off'. Taken in conjunction with the only slightly more clear evidence on the question of the authenticity of the changes in performance produced by training, this assessment supports the conclusion that the case against the educational

utility of acceleration studies remains to be proved. In the interim, their potential practical contribution in the search for methods sufficient to produce the attainment of particular landmarks in cognitive development appeals to make the continuation of acceleration studies worthwhile. The balance of the evidence suggests that future studies should conform to certain guidelines if they are to make the maximum contribution possible on both the empirical and theoretical planes. The acceleration treatments used should be based on task or process analyses at the level of detail exemplified in the work of Gagne'(1968) or Klahr & Wallace (1970). They should, also include an extended series of relevant learning experiences involving the use of a wide variety of materials and presented in a sufficiently non-directive fashion to allow children to employ their own preferred modes of mediation....

It would be a rash reviewer who would suggest that solutions to these problems lie just round the corner. The road to the cognitive researcher's' hell is paved with such optimistic prognoses. Sufficient be it to say that the present tendency to tackle

complex issues with complex instruments is sufficien tly encouraging to tempt the writer to conclude with the assertion that in 1971 the outlook for research on conceptualization and in the wider area of cognitive development appears to be considerably brighter than in 1963(85).

Lastly ,it may be mentioned that research in this area is just coming up. It is, therefore, not possible to answer the question whether accelerated thinking can result or not. Over generalization in this area may be quite dangerous. But it appears that accelerated thinking under certain conditions and within certain elastic limits is possible. It is not impossible to teach atomic and set theories in the primary school by the new enthusiasts. But they are mistaken if they think that change of content or downgrading of content in itself is a complete reform, Substantial and complete reforms result only when relevant material drawn from the significant areas of human living as the subject of study itself is used to develop and improve thinking through imaginative approaches. Here, well- structured experiences need to be designed,imparted and then evaluated.

Problem at the focus of attention, reasonable freed

including flexible time-tabling and permissive and responsive environment go a long way in imparting inquiry skills to the pupils. Under these conditions, children accept the teacher's word after full consideration of the relevant data including the necessary experimentation. In this triple process of concept formation, concept attainment and problem solving, incomplete hypotheses expand to complete hypotheses by appropriate rectifications where one strategy, if it does not work, leads to another strategy. Children then take into consideration the significant aspect(elements)of the problem. During attack on the problem, they develop their own insights and gather and develop new information, knowledge and skills. The consequent knowledge obtained through self-involvement in the problematic situation is not only meaningful but also very stable in character. It is no wonder then that cognitive structures are modified materially and are available for subsequent use. This availability is not as direct as one may get the impression because our environment under natural(or even otherwise) conditions creates expectancies and violates them off and on; and this exerts an educative influence. This is a more difficult job for the teacher to accomplish in comparison to the teaching of the few isolated junks of advanced knowledge in the school syllabus. The teacher's difficulties increase manifold if he looks to the educational psychologists for help and guidance. This is, atleast, true in this country(17).

...

SECTION C

SURVEY OF RELATED STUDIES

ON PROBLEM SOLVING

IN SCIENCE.

1. Status of Research:

About sixteen years ago, D.Wheeler said," It is strange that at a time when there has been a rapidly increasing need to select and educate those who are specially suited for training in scientific work, the psychological study of the processes underlying scientific reasoning has been so widely neglected"(86). About eleven years ago, it was alleged that research in American Science education is inadequate for it suffers from limited imagination, evaluating outgoing practice instead of ' functioning as beacon and too many no significant differences studies' making suspect both the tools or the hypotheses under study (87). The same tradition appears to continue when Wayne W.Welch, while reviewing research in science education at the secondary level for the biennium 1968-69, says:

> ...It is a distillation and characterisation of the research efforts of science educators. Specific references have been pointed out in the various sections and several documents have been used to illustrate the points. Much of the work appears fragmented and uninspiring. Perhaps this is due to the fact that motivation for most of the work is completing some external requirement, a thesis or funding report, rather than generating knowledge

about the educational process. This hypothesis is supported in some sense by the quality of work that appears in a few places that have on going research projects associated with them. There is hope for educational research only when experienced researchers are able to devote the majority of their time to seeking the answers to important questions. At present, we are far from that goal(88).

At home, the situation in regard to Research in Science Education is quite depressing because Research Career in Science Education is the least rewarding. In fact, it is a research desert characterized by the lack of personnel, problems and publicity. It is recently that the National Council of Educational Research and Training and the All India Science Teachers Association have done a bit in this direction. In a very recent publication on a Survey of Research in Education, D.B.Desai and Sunirmal Roy deplore the quality and quantity of researches conducted in the area of curriculum, methods and textbooks for ' most of them have centered round the surface problems, and that too, covering the middle and secondary school stages only'(89). Out of ten studies reported four are in science, five in mathematics and one in Home Science. They then add:

> Research in curriculum and instruction deserves more attention than it has received so far. Even

in the advanced countries of the world, it is criticized as being inadequate, out moded and not properly designed to meet the needs of modern society. Against the background of striking curricular developments in those countries, the school curriculum in India is narrowly conceived largely out of date.

.... The studies on teaching methods hardly made any significant impact. Most of them compared some sort of practical biased approach of instruction with the traditional 'chalk and talk' method and branded the former as progressive or effective without caring to go a bit deep into the fact as to why, in what way or how it was so. In a word, no approach was made towards a consistent theory of teaching. Another most significant fact about these studies under review was that quite a large number of them was not grounded on sound methodology. The limited scope of their sampling restricted, to a great extent the validity of their generalizations(89).

On reflection, these critical remarks apply to the frame of reference rather than to individual studies which when seen cumulatively do strike a note of optimism. This view point is confirmed by the studies summarized below(90).

2. Varied Studies Surveyed

G. Stanley Hall studied the contents of Children's minds and thereby emphasized the importance of primary or first hand experience rather than bookish knowledge. He further stated a well known educational principle (known to unknown) "Concepts which are most common in a given locality are the earliest acquired, less frequent ones came later, no one child has all the misconceptions recorded, none is free from them.... The fact that children see objects a hundred times without acquiring consciousness of them suggest that we need to converse with children about common things"(91). Keen studied children's reasoning and found that children under study has 'weak urge for experimental verification', children are sure to develop illogical concepts if teacher does not take sufficient care while introducing new experiences to them(91). Deutsche, examined the nature and development of causal reasoning- a phase of children's thinking in the context of the Geneva School with the aid of the problems with and without experiments. She noticed a gradual growth of reasoning in contrast to stagewise growth as suggested by Piaget. Secondly, she did not find the detailed classification of reasoning into seventeen types useful as found by Piaget. Thirdly, school

suggest that we need to converse with children about [illegible]

found that children under [illegible]

[illegible]

concrete [illegible] not take sufficient care while

[illegible]

experience explained specific responses to the specific questions which she suggested had direct and indirect implications for teaching and training children(91). Oakes investigated qualitatively children's explanations of natural phenomena and concluded that all age groups regardless of mental ability and grade gave all types of answers. Further, adult groups did not follow any definite procedure while explaining unfamiliar phenomena. Thirdly, he did not find a definite stage in children's thinking characteristic of a given age(92). He thus confirmed the earlier findings of Deutsche, Keen Hazlitt, Johnson and Josey, Susan Issac and Haung, who had found that both American and Chinese children 'gave naturalistic factual and logical explanations of phenomena'(93). W.F.King, while exploring the development of scientific concepts of children (N = 1235 between 5 to 12 years) with the aid of seventy questions suitably classified into five categories: 'Length, weight, time, direction; volume and weight; mainly mechanical principles, lever , wheels, living things: seasons and shadows concluded;

(a) Children at all ages gave all sorts of responses.

(b) Like Oakes, no stages in causal reasoning as propounded by Piaget were noticed. Response appeared to be, largely speaking, the function of question rather than solely the function of age.

(c) Some children showed difficulty in verbalizing their concepts which in fact they had understood as earlier reported by D.H.Russell. He then added:

Perhaps, there is a need about eight or nine years of age for the harnessing of this experience so that knowledge can be obtained by other, though not necessarily more formal, means. These experiments have shown that children of primary school age have accumulated a knowledge of scientific facts and that this knowledge increases with age in some cases very steadily. Some of the answers had to be obtained by reasoning on the basis of past experience and these also showed steady increase with age upto 8 or 9 years. Beyond that, a priori reasoning was not sufficient & adult guidance and explanation seemed essential, at least, in concepts relating to estimation of length, direction, weight and volume(94).

Banks studied the development of children's thought (11 + to 13 +) with the help of demonstration experiments which illustrated certain scientific principles. The subjects were low I.Q. pupils studying in a secondary Modern School in England. His main aim was to find out the relationship, if any, between the kind of answer given

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volume (94)

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not necessarily more formal means. These experiments have shown that children of primary school age have accumulated a knowledge of scientific facts and that this knowledge increases with age in some cases very steadily, some of the answers tended to be obtained by reasoning on the basis of past experience and these also showed steady increases with age up to 8 or 9.

Some children showed difficulty in verbalising

and the age and I.Q. of the individual pupil. Deutsche's classification(materialistic and non-materialistic) was used. His results showed that these children can explain experiments which are performed before them intelligently. Second-ly," age and science teaching had a greater effect on the ability to draw conclusions than did I.Q. but those with high I.Q. did better in the number of explanations in the higher categories(95). Using auto-instructional device, Keisler and McNeil found that contrary to the view of Piaget, six and seven year old children can give acceptable scientific explanations for physical events. They can not only learn abstract principles but also with some practice, would probably show' more facile expression and more accurate use of scientific language in the solution of new problems'(96). Navarra investigated the conceptual development of his own son (very young and above average in innate ability) over a period of two years. This study is rich in detail and the observations are first hand. Moreover the observations were based upon informal conversations. The most important findings of his study were:

(a) The development is gradual and its most interesting and characteristic feature is the long period necessary for integration during which the child gathers together and inter-prets for himself the experience encountered in highly diverse situations, e.g., seeing water in its different forms and distinguishing it from steam or distinguishing steam from smoke.

(b) In this development, there appeared the evidence of ' gradual differentiation and development of expectancies, testing ideas, analysing experience, finding positive and negative instances and maintenance of an inquiring attitude' etc. Even the earlier insignificant details and concerns were seen to have initiated growth later on or constituted a progression of events in the total frame of reference(97). The study, however, lacked comparison with the findings of Piaget.

In an observational and analytical study on thought processes of school children and college students, Buswell found ' variety rather than similarity in the sequence of thinking'; and failure to solve the problem attracts all sorts of hypotheses. Benjamin Burrack concluded that even undergraduate students failed to distinguish among different methods of attack on problems involving induction, deduction and geometrical analysis. On puzzle type situations, Heidbreder found that reactions and sensitivity to problems increased with age; a gradual change with age from a more subjective attitude to a more objective attitude and characteristic and individual reactions to the problems apart from the fact that the 'general pattern of the solution became more general or definite but new rigidity set as the age increased'(98). Mumford found that

training experience and practice influence thinking only if it is regarded as a mental skill based upon innate capacity. She suggested that educative experience is a vital experience in the life of an individual and needs to be handled with great care so as to develop self confidence and persistence in the face of 'disappointments and threats of failure during problem solving'(99). Bloom and Broader showed that the successful problem solvers differed from the unsuccessful ones in respect of the following variables: ' ability to use rather than the possession of the total fund of information; extent of thought brought forward on a problem and attitude towards reasoning, confidence in the problem and the introduction of extraneous considerations into the problem situations"(100). Employing the combined use of experimental statistical and introspective procedures Wheeler concluded that children possess logical reasoning at much earlier age than hitherto assumed by teachers; and ' most of the elementary schemata necessarily for valid reasoning are already within the capacity' of the seven year old children(86). Here, one should not dismiss straight away the very dependence of young children on first hand experience.

In another experimental study of experimental problem

solving by Durkin which resembled Heidbreder and Mumford's work, it was aimed to examine the effect of the nature of the problem solving process and the appropriateness of the concepts used to describe the behaviour involved. Subjects were asked to talk aloud as they proceeded ahead with a well organized series of two dimensional puzzle situations. The problem solving behaviour evoked by these puzzles could be photographed. At the end of the experiment, each subject was asked to retrace his whole situation from the beginning to the end. Any point of interest was discussed. The main findings of this study indicated:

i) Problem solving behaviour in human adults is never at random inspite of the fact that they may not see the relevance of their moves as judged by the goal to be attained.

ii) Three types of solutions were distinguished, namely, trial and error, sudden reorganization and gradual analysis which could be termed as three distinct forms of thinking. Certain transitional cases showed that such distinction was difficult to maintain showing thereby the existence of continuum.

iii) Observation, recall, seeing relations, attention to goal, manipulation and inference were the processes present in all the three forms of thinking(101).

In conclusion, it is not known at what age formal reasoning begins. This age is found to be quite variable due to cultural differences and individual differences within the same culture. The most important question still left unexamined, is this:, whether each individual passes through these stages in succession as enunciated by Piaget and Inhelder or he is able to pick up the higher stage without having developed in him the preceding stage. In other words, this means: Is skipping stages in individual development possible? If this is found to be so, we have yet to know the relationship between the size of the jump and the various conditions both within the individual and outside, that make such jumps possible. In a restricted sense, the area of concept formation is also equally full of problems; possession; and availability of concepts verbally (Smoke); Catergorizing and conceptualizing (J.S.Bruner, Goodnow & Austin) ; relationship between intelligence and types of Piagetian concepts developed(Beard); Varied behaviour in structuring problems right from childhood to late adolescence (Luswell); lack of clarity and distinction among various methods

of attack; clear formulation of the problem, preliminary survey of all aspects of the presented material, analysis into major variables, locating the crucial aspects of the problem, application of the past experience, varied trials, control elimination of the sources of error and visualization (Benjamin Burrack); distinction among different types of solutions; trial & error, sudden reorganization and gradual analysis (Durkin); role of general or specific experience of concept formation; & problem solving(Maier); and characteristic differences in successful and unsuccessful problem solvers.

" Scientific thinking is largely a matter of good thinking habits, " says E.A. Peel(102). It is in the light of this definition that we will survey some more studies on problem solving in general as well as on science teaching relating to laboratory work, scientific inquiry and problem solving in science. All science teachers, largely speaking, try hard to develop good thinking habits among their pupils.

(1) In 1925, Carpenter investigated the comparative effectiveness of laboratory and demonstration methods over 1,000 subjects and concluded that ' pupils equally succeed well if success is measured by instruments which measure

the same abilities as are measured by these tests, namely specific information and ability to think in terms of chemistry". In 1958, Brandwein, Blackwood and Watson [illegible] the tests of Carpenter and commented that both the groups could succeed equally well independent of the above [illegible] methods on the basis of textbook knowledge alone(103).

(2) In 1928, Horton attempted to probe further [illegible] confirmed the above mentioned finding of Carpenter. [illegible] experimental groups were given: Individual laboratory [illegible] without direction, individual laboratory work with [illegible] direction, individual laboratory work with a manual [illegible] direction and demonstration by the teacher. His concl[illegible] was ' no reliable results appear in the testin by th[illegible] ordinary written examination neither by the [illegible] the school test". With the laboratory tests(non [illegible]) he found the following differences in ability i[illegible] and manipulate apparatus and to solve problems([illegible] projects) in the laboratory. In 1958, Frings and [illegible] confirmed Horton's findings(104).

(3) Atkin studied the role of accuracy of response [illegible] type of response (appeal to authority, use of [illegible] appeal to experimental and original explanation [illegible] formulating and suggesting tests for hypotheses [illegible] Elementary School Science Learning Experience. His main finding was that'pupils are more active, successful [illegible]

they select and work on their problems"(105).

(4) In an experimental study, Lahti ascertained the effectiveness of laboratory in developing student ability to use the scientific method to evaluate the effectiveness of the teaching methods and to design and construct laboratory experiments, and instruments. His evidence supported the following statement of Kruglak;

> There is hardly a better method of teaching scientific method than the one which places the student in the same position as the research scientist, where he faces the same difficulties, commits the same mistakes, suffers the same accidents and explores the same blind alleys(106).

(5) Extending over a period of seven years, Kruglak has investigated some behaviour objectives for laboratory instruction, experimental outcomes of laboratory instruction, achievement of physics students with and without laboratory work, the measurement of laboratory achievement; the effect of high school physics and college laboratory instruction on achievement in college physics and evaluating laboratory work by the use of objective tests etc. He confirmed the findings of Carpenter and Horton(106).

Brandwein, Watson and Blackwood have emphasized the importance of laboratory work in their studies. Children then learn to work carefully,accurately, predict from first principles and select, design, search and improve laboratory equipment and techniques. At about the same time, Brown also made a similar type of investigation but without using any statistical niceties and concluded that ' students who had physics laboratory work in high school were inept at naming or identifying the function of equipment which they were known to have handled in the high school'(107).

(6) Muthulingam also attempted to assess the scientific thinking ability, attainment in science, attitude toward science and interest in the scientific field of boys and girls studying physical sciences in the fifth year of the secondary school in England and Ceylon and contribution of the factors in the schools, such as, the type of science course, the laboratory facilities and methods of teaching science, etc. " A battery of tests was constructed to measure the various aspects of scientific thinking; definition, problematic situation, reasoning, application of principles and ability to analyse and observe etc. Regarding application of principles, he says, " Results of the sub-test on the application of principles in England seem to be in favour of a method of teaching, emphasizing theory and restricted laboratory facilities. " He further adds, " There is, however, evidence for better power of observation

by the provision of good laboratory facilities and practical method of teaching(108).

(7) Charren George investigated the effect of open ended experiments on the achievement of certain objectives of science teaching. Six M.C.A.(Manufacturing Chemists Association) experiments and six comparable traditional laboratory exercises were chosen for the experimental and the control group. The M.C.A. experiments involved certain elements of the scientific method like seeking solution to the problem, to make predictions and to set up apparatus and control experiments. Attempt was also made to test some attributes of critical thinking like ability to interpret data and to associate with the nature of proof etc. The study was carried over 268 students. His main conclusions indicated that open ended experiments like the M.C.A. do succeed to develop scientific attitudes, skills and motivation. Secondly, both open and traditional exercises do result in significant learning. Thirdly, there is no conclusive evidence that a laboratory approach has led to improved critical thinking in chemistry (109).

(8) Butt has studied the degree to which children conceptualize from science experiences. He confronted 24 pupils from the fourth, fifth and sixth grades with science

experiences in order to see concept development arising out of this new experience. Four other questions were also examined: relationship between concept development and chronological age, intelligence and attainment in science, influence of a given concept in the development of a different concept and recognition of a given concept in a new situation or experience. The concepts under study related to displacement, inertia, action, reaction and depth pressure relationship. The experiments were done under three different conditions, namely experience phase, question phase and a manipulation phase. The findings of this study do not support the popular assertion that meaningful concepts will definitely emerge when a child is provided with proper experience or environment and the free opportunity to experience certain perceptions(110). In the opinion of this writer, it would have been better if Butt had considered the causes that contributed to this failure by analysing their wrong responses and interpreting them.

(9) Szekely attempted to investigate 'knowledge as the starting point of independent thinking', by presenting the same problem in three different forms. Different subjects were used for three forms of the same problem. Consider the following problem.

Fig
Showing Szekely's application problem

(a) The candle is lighted and the subject has to explain why the level falls down.

(b) The same arrangement. The subject is asked what would happen if the candle were lighted.

(c) In this case, there is opportunity to find solution through free experimentation(111).

Szekely believed and, therefore, hypothesized that knowledge can be investigated in its' function of end result, starting point and medium of learning and thinking'. He found that knowledge gets reorganized in the process of thinking which starts from the object of thought. Secondly, the three different forms of the situations or presentations of the same problem differ only in the extent of difficulty of restructurization which, in its turn, depends not only upon the piece of knowledge (needed to solve the problem) but also upon the total situation. In addition, Szekely carried out quite a few studies on productive processes in learning and thinking; and then posed the following problem to himself yet to be solved since it was posed about twenty five years ago:

It is well known that different individuals

who have the same knowledge show great differences in the original application of this knowledge. Does the applicability of the knowledge depend solely upon the differences in individual endowment or is it also dependent upon the method of learning and teaching? Is it possible to increase the productive applicability of the knowledge that is the capacity for creative thinking by the improvement of the methods of learning? (111).

Two methods of learning were compared, namely, modern method and the traditional method. As learning materials, a few laws of mechanics served which were to be applied to a relative different task, namely, the problem of two spheres.

The main findings of this study indicated:

a) If judged by the frequency of successful solutions alone, the modern method is superior to the traditional method even when " endowment is taken into consideration." But Maltzman, Eisman and Brooks (1956) have failed to duplicate this finding, According to them," Either method, or a combination of the methods, produced more solutions than a control group with no training but there were no significant differences among the three experimental groups"(111)

b) Productive knowledge evoked in the process of problem solving and the verbal reproducibility of definitions are mutually exclusive of each other. This means that the rote memorization of definition or facts will not guarantee the solution of the problem(111).

c) Improvement of the learning method improves comprehension of the learning material which fosters independent productive thinking later on(111).

It is necessary to replicate this type of study by drawing concepts from the new curricular programmes developed in the wake of Revolution in Science Teaching in relation to several outside variables over a very large sample.

(10) In his investigation of the thought-processes of a group of fourteen year olds during the solution of a scientific problem, Kyle showed, " that abler pupils tend to progress by hind sight." " They tend to jump to the end of certain phases and then to return to fill in the blanks... " A problem only becomes real for person when he has some rudimentary foresight of a tentative solution..." He further showed that ' a doing group went further towards a solution than a thinking group'. This is so because a doing group can rectify its mistakes in the process of experimentation(112)

(11) At the higher age group, Whellock attempted to inquire " into how far scientific method is gained from Science Education." His subjects were sixth-form pupils and military college students. After partialling out differences due to intelligence, he showed a significant relationship between the scores on method and attitude and the scientific background(113).

(12) Mealings investigated certain aspects problem solving in science principles among secondary school children above 100 in number varying in intelligence. Most of the problems were original ones and in fact seem to meet the requirements of complex human tasks as needed in such type of studies. The general aim of his investigation was to understand from first principles, the solving of scientific problems by the adolescent pupils in a normal school- setting. More specifically, his aims were to investigate the relationship between the problem solving ability(at the formal level) and the mental age and to consider the influence of personal attributes on the problem solving ability. Sex differences were also considered. Two series of four experiments in each were administered among two groups of children in turn. A case study approach was employed and the responses were recorded verbatim, then arranged and analysed to see the course of thought on each problem. The main results

of his study indicated that problem solving in science is more related to intelligence than to chronological age.(This is understandable). There appears to be a minimum mental age of 13 years before a child can reason formally about a problem and there is a time lag between the empirical solution and the formal solution. Taking an overall picture, Mealings says we should not expect children to solve abstract and theoretical problems in science until they reach a mental age of 16 plus. It is also possible, at this stage, to undertake topics requiring an understanding of matrical proportions, i.e. Boyle's Law, Ohm's law and theoretical problems concerning moments and specific heat in physics and the laws of chemical combination in chemistry(114).

(13). Neal attempted to ascertain specific procedures that aid children in developing the ability to use methods of scientific inquiry in grades (I to VI) in the laboratory school of Colorado. The author attempted to determine the elements of problems solving to develop and select illustrative teaching techniques, which promote growth in the ability to use the methods of scientific inquiry, to judge the effectiveness of the various teaching techniques and lastly to observe and describe the kind of covert behaviour characterized as the method of scientific inquiry.

Identifying and stating problems, selecting pertinent and adequate data, formulating and evaluating hypotheses and seeing relation were the various methods of scientific inquiry selected. He then concluded that children not only developed scientific interest, confidence and responsibility by the practice of scientific method but were also capable of developing abilities in practising the above mentioned elements of the scientific method(115).

Partly influenced by activity and core patterns of curriculum(including basic notions of community school in the U.S.A., the U.S.S.R., and Phillipines) Willard J.Jacobson in a paper entitled ' Science Education and the Development of Abilities to cope with problematic Life Situations' developed a working frame of reference in which SHOULD rather than HOW questions receive first priority. His main assumption is that " We can and should help individuals and groups to develop the abilities to recognize and cope with problematic life situations of which they are a part". He then sought 'operational answers to the question of how these abilities to cope with problematic situations, could be developed'. For the development of these abilities, he suggested the following three phases: Use of proposals based upon past experience dealing with the development of these abilities through science education; analysis of the

whole act of adjusting with the life situation, and consideration of the same in terms of judgements and values. He thus advocated the use of life situations for their consequences can be seen and felt first hand which, the process ,will help adolescents master dilemma in their own characteristic ways. To quote Jacobson:

> New relationships are difficult to perceive, and a group may eventually reach a point at which they are stymied. In such situations, it may well be fruitful to have a period of rest from the intesive examination of the problem. After a period of time, they will necessarily view the problem from a different point of vantage, and hence, new relationships may appeal. The mysterious period of ' incubation' that has been suggested by Helmholtz and Poincare does have this realization. During the period of rest, some of the extraneous material that was, perhaps, blocking their view of the situation may be forgotten. With the elimination of these elements, the discovery of a new key element, or the new view from a different vantage point as the result of a passage of time, new and fruitful suggestions are more likely to appear(116).

(14) In a practical piece of research, Fleshner has emphasized the importance of children's everyday experience in teaching abstract concepts in Physics. Researches of N.E.Weaver and E.N.Madden have advanced two conditions for success for problem solving, namely, the ' presence of corresponding knowledge' and the ' mastery of research operation'.For example, the concept of weight involves weight for all bodies, earth's pull and force. Open- ended questions were posed to the children. Every child could answer at least a part of the problem. An interesting finding emerged that eighty per cent of the subjects were of the firm opinion that ' bodies which they had not measured had no weights'. Thus there is direct educational implication of the above: the definition(weight here) should not be taught and stressed too much in science teaching but on other hand, it should stem from their floating ideas (living practice) when a given theme is introduced in the classroom (Goriachkin,117).

(15) Stendler is of the opinion that superior intelligence does not imply' superior performance both in linguistic and scientific fields". She emphasizes the importance of well-structured childhood experiences which facilitate learning later on. She explores the following hypothesis: "that certain kinds of childhood experiences structures an individual's perceptions of the physical world, that the percepts are stored

as information cell assemblies in the cortex and that the neural reservoir facilities the learning of concepts in the physical science." Then she discusses the nature of experiences that might contribute to the building of such a neural reservoir. She then suggests the use of teaching models that will help the elementary school pupils develop functional understanding and skills needed for the physical science(118).

(16)N.Vaidya investigated problem solving in science among certain groups of adolescent pupils(15 +). The results of the study indicated that contrary to Piaget's view, the adolescent pupils do not hesitate to criticize data. Secondly, there is a general tendency among adolescent pupils to set up hypotheses which they test against the given data. Thirdly, a poor problem solver appears to stick to one idea at a time stubbornly and, later on, ceases to think of alternative ideas. Consequently, he gives up the problem in disgust. When problems were analysed for their mathematical structure through the technique of factor analysis, the following four factors appeared: Attainment, Practical, Interest and Adjustment. The outstanding conclusion of his study was that Problem Solving Processes derived from different problems as well as analysed differently(using Guttman Scale) confirm and support Piaget in principle (119). But, at the same time, it may be added that the study lacked hypotheses as well as suitable study population(N= 60; and N=31).

(17) Vijaya Lakshmi investigated the thought processes of backward children(12 +) with special reference to the Schemata of Combinatorial Grouping. She also examined continuities and discontinuities in their thinking with the help of scaleogram of problem-solving processes. The coefficient of fluctuation came out to be 49.7, which was on the high side. But when the various responses or thought- processes were appropr-iately grouped, the coefficient of fluctuation came out to be 5.6 per cent, that is, within acceptable limits. This showed that appropriately grouped processes of thought within a restricted age-range constitute a Guttman Scale(120). Using Piaget type tasks in arithmetic, K.R.Sayal, concluded that items relating to the algebraic symbols and the scheme of proportion are hardly mastered by the 11 year old children. Secondly, they are capable of showing more thinking than they are deemed to have as judged by class teachers on their achievement in mathematics. Thirdly, the top group was influenced more by the form rather than the content of the problems in comparison to the bottom group when attempt is made intentionally to invite wrong answers, a finding consistent with Piaget's ideas. Then he added:

> Through questionnaire technique, it is not possible to find exactly the reasons for the errors incidentally committed on the problems, From indirect evidence, the reasons appeared to be the following:

poor mathematical v cabulary, failure to add, subtract, multiply and divide exactly, underdevelopment of the schema of proportion in particular, failure to generalise their thinking to algebraic symbols and,possibly, the use of more mechanical ways of thinking than intellegent understanding of the problem(121).

(18) Robert S.Tannenbaum used an entirely different approach, while developing the Test of Science Processes,namely, Observing, Comparing, Classifying, Quantifying, Experimenting, Inferring and Predicting. This study is unique in the sense that very little is known about the emergercy of these processes at various age levels. When the test is looked at depth, it does not use problems involving a continuous chain of reasoning, all of the test items being, of course,process based and of the multiple choice variety, Moreover, the various processes in relation to known tests useful for interpretation of the same processes lack factorial evidence. Still, the author at least appears to have achieved the main purpose of the instrument: 'Measurement of Progress towards Behavioural Objectives'(121). But it is not known in what order and at what ages the various processes are mastered by pupils. In contrast to this study, R.M.Misra, using Piaget type tasks, investigated the role of hypotheses formation in solving problems inhering a continuous chain of reasoning among X grade science students. The main findings of his

study indicated:

a) A given problem is solved over a wide I.Q.range. A low I.Q. pupil may solve the problem successfully whereas a high I.Q. pupil may fail on it.

b) There is no significant difference between the top and the bottom group in regard to the average number of hypotheses set up. It is of interest to point out that the bottom group identified two other variables, namely, the tension and elasticity of the thread which were not suggested by any member of the top groups

c) When the mathematical structure of the problems used was analysed through factor analysis, the following five factors appeared: General Adjustment, Seeing the Problem as a whole; Formulating Hypotheses; Interest in Generating Difficult Problems(whose answers they do not know, that is, posing such questions on cow and cycle); and newness of the problem.

d) There is á general tendency among adolescent pupils to set up all sorts of hypotheses but, at the same time, they have aw-fully failed to test the various hypotheses. The main findings here is that their minds have not become truly experimental(123).

(19) This finding receives support from a paper on Promoting Intellectual Development Through Science Teaching by John W.Renner & Anton E.Lawson. Using two Piaget tasks

on the conservation of Volume and the Exclusion of Irrelevant Variables, they found that ' out of the population from which physics students are drawn, not many are formal operational' as shown in the table below:

Table 2.1

Showing the number of adolescent pupils grade-wise and sex-wise possessing ability to conserve volume as well as to exclude variables.

S.No.	Grade	Population		Conservation of volume.	Exclusion
1.	XI	Male =	45	26	23
	N=99	Female =	54	19	14
	XII	Male =	50	34	20
	N=97	Female =	47	8	16

When the same two problems were administered on 185 college freshmen, only 133 and 77 could show successfully the conservation of volume and exclusion of variables behaviours. This shows that even the majority of College freshmen have not moved deeply into the formal operational stage of thought (124). In another informal study on 11 college freshmen, Sharon Bastian & others, using four Piaget adapted tasks (these were the pendulum, the inclined plane, angle of incidence and reflection and volume) found that ' none of the eleven subjects performed on the formal operational level'. In other words, this meant that they found logical experimentation difficult. Secondly, there did not exist any significant

correlation between scores on Piaget tasks and the other outside variables like standard achievement test scores; current grade point average scores; predicted grade average scores; and high school percentiles. Thirdly, scores on Piaget type tasks were least influenced by sex, age, and major area of study. Why? The reason could be that approach to the courses which they had studied was least inquiry centred(125). John W. Renner & Anton E. Lawson remark (in the context of Science Curriculum Improvement Study Project under the guidance of Professor Robert Karplus):

> Our research has shown us that the level of thought of junior high school students and college freshmen can be changed by providing them inquiry centred experiences in science. We believe that the principal reason our research has shown an increase in the thought levels of students is because we accepted that most of them participating experiments were concrete operational. That squarely put upon us the responsibility for providing concrete experiences with the objects and ideas of the discipline. These students were involved in actually creating some knowledge of their very own. We know that it was the first time some of them had been given that opportunity. We believe that actual involvement with the materials and ideas of science and being allowed to find out something for themselves accounts for movement toward and into

formal thought which we found.

..... This teacher is not a teller, he is a director of learning. Traditional teaching methods embrace the notions that (a) teaching of telling, (b)memorization is learning, and (c) being able to repeat something on an examination is evidence of understanding...these points are the antithesis of inquiry... The development of formal thought must become the focus of attention of every teacher in the country...the central role of the school must be to teach children with form not objects- in other words, to move students into the stage of formal operational thought. Science has the structure to enhance greatly the achievement of this objective. We must not blow our chances to make a maximum contribution to education in general and education in science in particular! Let us establish an enviornment in our classrooms that encourages and promotes formal thought(124).

It is a grand hypothesis which needs to be tested under as many diverse conditions as feasible. In another interesting study, using the well known pendulum on a very wide age group 10-50 years, Kohlberg and Gilligan reported that a ' large percentage of the adolescent population is not

formal operational'. The results obtained by them were:

Table 2.2
Showing the percentage of adolescent population able to reason formally in various age groups.

S.No.	age group in years	Percentage
1.	10-15	45
2.	16-20	53
3.	21-30	65
4.	45-50	57

It appears that adolescents are not making full use of their ' talents and tools', this percentage being quite high even within the age group 16-20 years(126).

(20) W.F.Archenhold investigated the concept of 'potential, electrostatic and gravitational, including related concepts such as work done and energy' as held by a group of sixth formers in the age group 16-19 years in the north of England. Twenty five tasks were designed which tested their understanding through a series of theoretical and practical situations in the above mentioned areas in physics. These pupils not only exhibited limited understanding but also misunderstandings which, in a way, reflected their difficulties in grasping these concepts at advanced level. When results were factor analysed, using Hotelling method, a strong intellectual/ educational component appeared while 'Varimax rotation isolated two factors containing tasks associated with potential and work done respectively(127).

(21) Robert Eugene Norton, attempted to assess Children's Ability to Solve Problems in Science developmentally using a test(T.S.P. Tab Science Puzzler) on adolescent pupils studying in grades four to six. He investigated relationships between problem solving ability on one hand and other variables like previous science knowledge; I.Q., age and reading ability; and selected cognitive factors of intelligence. Main findings of this study indicated:

(i) Problem solving performance is related to previous knowledge, a finding consistent with Wellock on a higher age group.

(ii) Although the selected cognitive factors are not related to total problem solving performance, flexibility and speed of closure and reasoning are related to the problem- solving subtasks, problem orientation, problem solution and data analysis.

(iii) Based on the correlation between problem-solving performance and I.Q., age and reading ability, no evidence was found to support a relationship between problem-solving, I.Q. and reading ability.

(iv) Chronological age appears to be related to problem solving in certain areas(128).

(22) It is possible to see the same problem in a different context by making use of objective tests in which reliance is placed on the initial answers which are then subjected to advanced statistical analysis. A lead in this direction has been given by STEP (Sequential Tests of Educational Progress) which needs mentioning for its objectives according to the publisher are to measure several skills: picking up the problem, sharp formulation of the problem hypothesizing, designing experiments, interpreting data (also conflicting), developing objective procedures, evaluating evidence critically, using symbols and written materials, and their interpretations. Consider the following problem:

> Situation. You are the engineer directing a new dam project on a certain river. You have team of scientists, i.e. biologists, chemists, geologists, meterologists, and physicists in assistance on the project. You have to locate the dam in the best position and arrange for the hydro-electric power and the irrigation of the surrounding district which is a semi-arid zone region. The water level is to say 300 feet above the river.

Subject matter area	- Geology
Ability	- To identify and define a scientific problem.

On the following, the most important problem requiring your attention would be:

(a) To find the point where the river banks come closest together.

(b) To find the point where the largest and deepest lake could be built up behind the dam.

(c) To investigate the characteristics and structure of the rocks underneath the river bed & along the banks.

(d) To determine the least amount of inhabited land that would be flooded(129).

Like line spectrum, children's thinking is tested ability wise but, at the same time, a specific suggestion of value has been made by Gupta in another study when he says:

> It may be possible to conduct researches on the mutual relationship of purely factual and tests requiring the understanding and application, with both types based on identical subject matter. A high correlation may mean that the tests of the latter variety should be preferred because of their desirable influence on teaching and learning habits, whereas a low correlation may mean the desirability of both the types with suitable weightings. However caution may have to be exercised in generalizing any relationship discovered in small experiments because

there are other variables also, for instance, differences in the teaching practices noticeable in different schools, and so on, which may effect the result to an appreciable extent(130).

Inquiry Training

It is necessary to refer to Inquiry Approach in science teaching in passing. J.J. Schwab has aptly remarked that the 'Problem now facing teacher of science is no reblooming of a perennial' but it is a ' mutant- new in so great a degree as to amount to a difference in kind'. He distinguished two aspects of scientific inquiries,namely, stable and fluid, the latter aspect relating to science in the ' making ' in which even the very principles of inquiry remain suspect(131). It is not only that it is the teacher who talks too much in the classroom but also it is again he who also asks questions about 97 per cent of the time. As children move up in the respective higher grades, this very teacher behaviour results in their becoming less empirical. In other words, they, instead of trusting their own concepts, begin to accept external authority in an unreflective manner(132). The Illinois Studies in Inquiry Training Project under the guidance of J.Richard Suchman began in 1957 and identified over the years the following ideal conditions for developing inquiry skills among

lr ntary school children: focus for attention; freedom (external and internal); and responsive environment in the words of O.K.Moore. Elementary school children are exposed to discrepant events which by their very nature compel them to analyse, for example, the erratic behaviour of a bimetal blade on heating and cooling. Films were made in quite a few school subjects like physics, biology and economics. They were forced through these episodes containing discrepant events with the aid of yes-no questions to seek their own explanations. Learn- is thus enabled to direct and control his own learning. Suchma regarded inquiry as a ' Process of Discovery' comprising the following four phases: searching, data processing,discovery and verification with a view to investigate several causal relations. Using other outside variables including known tests and scores on inquiry and subjecting the data to factor analysis, the following three factors relevant to success in inquiry appeared:

(a) Impulsivity factor: the capacity to leave beyond data to generate abstractions. Zero in on.

(b) Cognitive Control: the ability to handle and manipulat data.

(c) Autonomy. The second is related to this because for if you never leave the data, you will never construct the data(132).

Inquiry into science teaching is a never ending process until the dead end arrives; and it has to be shown so. Ben Strasser has shifted the focus of inquiry on teachers rather than pupil behaviour, another interesting research question (132). Alphoretta Fish, on the other hand, shifts the same on alternative methods of inquiry, thus, giving three different meanings to the term Inquiry(132). Le Von Blazer makes out a strong case for developing inquiry skills as one of the most important outcomes of instruction in biology. He thus supports J.J.Schwab, Anderson and Robert Gagne' for it provides opportunities for scientific thinking. Again he quotes Gagne' who sums up various writers on inquiry, " I judge them to mean, that it is a set of activities characterized by a problem solving approach of which each newly encountered phenomenon becomes a challenge for thinking" (132). John H.Woodburn in Discover and Describe stresses the investigative approach to science teaching by presenting puzzling events or situations to children which intentionally' offend ' their senses. The observable cognitive conflicts provide a ' realistic visible format easily communicable between student and teacher' (133). Using programmed materials, Robert M.Olton and his co-workers, tried to assess the extent to which' specified productive thinking abilities, can be taught to elementary school children'. Being a comprehensive project, they raised the following additional questions :-

(a) Are some productive thinking skills more

amenable to instruction than others?

(b)Can productive thinking skills be learned by children of all I.Q. levels ?.

(c)How are productive thinking skills affected by a classroom environment judged to facilitate creative expression?

The main findings indicated that use of programmed materials" led to an increase in the level of productive thinking in this large and representative group of fifth grade students" (N=704) at three levels of I.Q. included in the study. However, the extent of generality of training was limited, the main reason being the kind of problems rather than the kind of performance measures employed. Secondly, both the experimental and control groups demonstrated on demand simple cognitive skills, training being inessential. The latter, however, hardly use them in their day to day work. The complex tasks, on the other hand, necessitate the use of advanced skills which were not yet available but could be developed in training sessions. Specifically speaking, contrary to the findings of Covington and Crutchfield(1965), there does occur a gradual increase quantitatively as practice trials training sessions increase. The role of facilitating environment was also found ineffective at the end of the project because the treatment was particularly effective with students in non-facilitating environments. The

girls were found superior to boys on all types of problems. As research problems, they have suggested to re-examine the same problems with which they started by determining the presence or absence of cognitive skills at various age levels, finding skills amenable to practice in contrast to training or instruction and the quality as well as quantity of training sessions(134).

In another restricted study on' Hypotheses Formation can be Taught," Mary Ellen Quinn, using twelve film loops of 12 minutes duration each, the schumanian way, showed that both urban and suburban children produced statistically significant improvement in ability to hypothesize'. It is of interest to mention that the training comprised better recognition of the problem, distinction between empirical and non empirical based statement, observation of properties or behavi -ours of objects in the lo films, drawing of inferences, determination of empirical relations between observed and inferred variables and experiments for testing hypotheses(135). She thus confirmed the earlier finding of Richard C. Anderson that training sessions did help even the first graders on transfer tasks. These first graders constituting the one top thirds on the California Test of Mental Maturity, however, failed to show superior performance on the pendulum and the chemical problems. Sex also did not play any significant role (136). Through variable teaching techniques, it is possible

to teach facts and concepts of astronomy to two groups college freshmen with little effect on the students' understanding about science as measured by TOUS(137). Maureen A.Dietz and Kenneth D.George attempted to develop a reliable and valid tool for measuring the problem solving skills of children in grades one, two and three. These were: recognition, understanding of scientific principles necessary for the solution of the problem, collection of data and handling, if- then statements(138). But the study fails to answer the basic question. For example, consider the following two studies as well.

David P.Butts and Howard L.Jones in an-other earlier study on 'Inquiry Training and Problem Solving Skill in Elementary School Children' developed an inquiry training programme as suggested by Suchman whose outcomes could be measured by an instrument especially developed for this purpose, namely, Tab Inventory of Science Processes(TISP). A child inquiring into a problem shows the following behaviours; searching, processing data, discovering, verifying and applying concepts to new situations. They intended to investigate the effects of training sessions on the problem solving behaviours of children as well as the role of outside variables like intelligence, sex, chronological age and factual knowledge in changed problem solving behaviour consequent of the instruction. They also examined

whether inquiry training led to meaningful concept development, using sixth grade students(N=106) and inquiry sessions extending over three weeks daily, the main finding indicated that when exposed to guidance, there resulted enhanced problem solving behaviour. Secondly, changes in problem solving behaviour were insignificantly related with tested intelligence, chronological age, sex and factual scientific knowledge when compared with the control group, the above mentioned variables did not appear to play significant role while drawing benefit from inquiry training. Then they remarked aptly:

> Much discussion has been given to the relationship between meaningful concept development and inquiry. The results of this study do not support the assertion that meaningful concept development results from inquiry training. Children who were successful problem solvers on TISP were not able to apply the concept to a different situation. Why ? Is the application of a concept to a different situation an adequate criterion for meaningful concept development? Were the situations' too different' for the child to see the relationship(139)?

At the same time it is also necessary to determine why a group of children fails to show changes in problem

solving behaviour and relate them to their personality make-up. Robert E.Yager and John W. Wick do support that certain phases of pupil outcomes are definitely the result of varied intentional teaching strategies but, at the same time, they provide the following disturbing conclusion that there is no significant difference in the mastery of the major concepts and facts of biology (as measured by the Neslson Biology Test) by the students among the three emphases used by the teachers of the study(140). In his writings, J.S.Bruner has talked of discovery, structure, early readiness and intuitive thinking. He gives a clarion call for discovering imaginative modes of inquiry among children so that each child is ' capable of going beyond the cultural ways of his social world, able to innovate, in however, modest a way, so that he can create an interior culture of his own'. 'For whatever the art', he says, ' the science, the literature, the history, and geography of a culture, each man must be his own artist, his own scientist, his own historian, his own navigator'(141). He is nearer to Plato as well as to Piaget for his learning by discovery is tied to their theoretical melange-' an environmentally dynamic version of contemporary developmental theory in conjunction with a twentieth century form of classical relationalism' (Lee S.Shulman). B.F.Skinner, Robert M.Gagne' and David Ausubel take the opposite view (141). Each of them takes a restricted view of learning, at least, at the starting point. A bit later, it becomes

a case of learning hierarchies: guided learning, and reception learning. While reviewing researches on discovery, Ausubel appears to state the following conclusion, a sort of educational disaster:

(a) That most of the articles most commonly cited in the literature as reporting results supportive of discovery techniques actually report no research findings whatsoever, but consist mainly of theoretical discussion, assertion and conjecture; of descriptions, of existing programmes utilizing discovery methods, and of enthusiastic but wholly subjective testimonials regarding the efficiency of discovery approaches.

(b) That most of the reasonable well-controlled studies report negative findings.

(c) That most studies reporting positive findings fail to control other significant variables or employ question able technique of statistical analysis. Thus actual examination of the research literature allegedly supportive of learning by discovery reveals that valid evidence of this nature is virtually non-existent. It appears that various enthusiasts of the discovery have been supporting each other research ... by taking in each other's laundry, so to speak,

> that is, by citing each other's opinions and assertions as evidence and by generalizing wildly from equivocal and even negative findings(142).

Instead, to' provide ideational scaffolding',he gives the concept of Organizers which in their different forms try to close the gap between what the pupil knows and what he is expected to know before he can master the task at hand. He thus restores the threatened status of the teacher in his scheme of learning(142). Regarding accelerated learning, it is of interest to refer to the founding of Project: Head Start in U.S.A. in 1965. Engelmann and Bereiter have reported startling successes with their slum children, for example, not only,they can speak complete sentences, solve simple arithmetical problems, read words and learning their spelling but also have registered increase in their intelligence. There are negative reports as well, for example, they are most of the time' tense, frightened and respond automatically'(143). Barbara Biber,here, remarks that the ' method through its effects on attitude and therefore on motivation, becomes a secondary determinant of how far the original learning goal will be realized' (143). Here, neither scrambled textbooks nor the high sounding educational technology like the Computer Assisted Instruction will be of use if used indiscriminately, for it may well kill curiosity, interest and individuality by ' making all men alike and not necessarily alike in nice ways'(143). Piaget is here conservative when he says:

We know that it takes nine to twelve months before babies develop the notion that an object is still there even when a screen is placed in front of it. Now kittens go through the same stages as children, all the same stages, but they do it in three months so they are six months a-head of babies. Is this an advantage or is not it? We can certainly see our answer in one sense. The kitten is not going to go much further. The child has taken longer, but he is capable of going further, so it seems to be that the nine months probably were not for nothing.

It is probably possible to accelerate, but, maximal acceleration is not desirable. There seems to be an optimal time. What this optimal time is will surely depend upon each individual and on the subject matter. We still need a great deal of research to know what the optimal time would be(144)

It is a million dollar American question, empirical experimental in nature whose research answer will illuminate Piaget's invariant clockwork of the order over the years. According to Lee S. Shulman, we have not yet exhausted fully the various creative approaches leading to the solution of this problem of cognitive acceleration for we have at the moment 'access only to opinions and personal prejudicies'(141).

It is of passing interest to refer to the study on the development of algebraic concepts among pupils studying at the junior secondary stage in relation to outside variables like levels of intelligence, sex and grades by J.N.Joshi. He standardized an algebraic concept test in Hindi containing seven categories like generalized numbers, directed number, equations, parentheses, substitutions, exponents and graphs. His findings indicated that all the broad categories except the one on directed number developed from grade to grade. Secondly superior intelligence is necessary for the formation of algebraic concepts. Thirdly, boys have a 'tendency to excel girls in the understanding of algebraic concepts(145). In another equally interesting and novel study on Analysing test Responses with symbolic Logic, Gary R.Smith attempted to assess pupils' success in understanding certain concepts of light with the help of multiple choice test items. He made detailed as well as distinct element-analysis of question and answer for testing pupil understanding on both. A fortran programme was written which would indicate the network of correct and incorrect responses. Twenty deductions were derived from five propositions. This approach has limited utility for difficulties lay in arbitrary allotment of symbols, the very designation of the class, confusion between symbolic proposition and unique statement of item proposition and omnibus nature of the test(146).

3. Overall Evaluation and
The Scope of the Problem

After having surveyed the field of human thinking with special reference to reasoning, concept formation, problem solving and school science education, it is now necessary to have another close look at the survey with a view to pose the present problem and state its scope. Science in its forward march does not pose impossible problems. Psychology, in our times, also claims scientific status. Therefore, like science, it must also pose its problems in their solvable forms for generating new objective knowledge. It is easier said than done for several variables intervene and, make in turn, the investigation of psychological problem becomes very difficult as is shown by the survey. Still, the findings of the various general as well as specific studies undertakes in different contexts not only within a given paradigm but also across the various ones, when consolidated, indicate:

(a) Thinking is multi-faceted in character. Its investigation, particularly speaking, of higher cognitive processes is considered to be a complex task. In our times, it ought to be the main job of the second psychological revolution to tackle successfully the various attendant problems, however, small they may be(147). The present survey reports several such studies against several theoretical standpoints undertake

with this objective in mind which attempt to make this complex problem a bit more transluscent.

(b) To facilitate this, thinking need no longer remain a 'ghost' like activity. As a first step, it is essential to short-circuit several definitional complexities if any worth-while progress is to be made at all. To illustrate, even a restricted field like problem solving has been investigated in the past under different heads. To surmount this problem, thinking in this study is regarded as a skill. Secondly, problem is defined as a task oriented situation having a clear cut solution with a view to facilitate the study of thinking processes.

(c) The survey clearly shows that it is theoretically possible to investigate any cognitive problem relating to any one of the following paradigms: S-R theories, Gagne's view-point, phenomenological theory, factor analytic approach, information processing, accelerated learning, Gestalt psychology and the Geneva school. It is not implied at all that one frame of reference is superior to another for, after all, it is finally a matter of individual choice in which attempt is made to catch the fish rather than seek specialization in the art of angling. This choice, again, is dependent upon the aims and object-ives of investigation, the nature of the very investigation, extent of controlled experimentation actually available and the physical facilities for carrying it out.

The present study draws its inspiration from Gestalt psychology, Geneva School and the factor analytic approach. Secondly, it goes a bit ahead, for in comparison to other workers in the field, it uses several problems having scientific flavour but, at the same time, each inhering a continuous chain of reasoning. Thirdly, the varied problem solving processes evoked during proble-m solving, largely speaking, possess clear cut solutions which, in turn, can be reclassifed or regrouped with definite advance hypotheses in mind. In summary, a promising line of inquiry of this nature is just perceptible in the area of thinking or problem solving. The present problem not yet tackled, is one among many, available in this area.

(d) To pinpoint, the present study investigates certain aspects of thinking through the medium of problem solving among science students of adolescent age who were matched on two variables, namely, intelligence as well as socio-economics status. When seen by exclusion, the following problems, of course, important receive little attention in this study:

(i) Problems relating to creativity variables.
(ii) Role of situational variables
(iii) Concept: formation as well as attainment.
(iv) Predictive studies.
(v) Acceleration studies.

(e) In continuation, these problems can't be ignored for a long time. The survey clearly makes out a case for investigating some of these general problems urgently. A few examples of such problems having some sort of association with our study are cited.

below:-

(i) At what age do children begin to manifest formal reasoning? What factors favour its early emergence? At what age do the adolescent pupils develop firm urge for experimental verification?

(ii) What variables determine vast individual differences in thinking? It is suspected that these variables are: intelligence, individual abilities, personality traits, task characteristics and varied instructional methodology.

(iii) Do sex differences exist in thinking at various age levels? If so, why? Are they genetically determined?

(iv) What exactly is the relationship between concept formation and its application?

(v) Why children fail to verbalize their concepts when they had, in fact, understood them? Is a correct test response given over a wide I.Q. range not only within individual grades but also across the various grades? Up to what extent can a given concept be down graded? Finally, do laws for down-grading concepts exist?

(vi) What is the role of hints and cues in the teaching learning process? Under what conditions do they really become effective?

(vii) Does thinking develop in stages? Do all the children go through the same stages? Particularly speaking, do the thinking processes develop unidimensionally? How to test this grand hypothesis?

(viii) What kinds of thinking processes does the training under experimental conditions generate? Are they really chips of the same block or different blocks?

(ix) Under what specific conditions does learning take place maximally? Alternatively, under what conditions do the acquired concepts really become disposable or acquire' measures of generality'?

(x) Lastly, what is the relationship between intelligence and the varied Piagetian concepts?

It is a long shopping list in which problems overlap. The present study, while investigating thinking, takes into account intelligence, grades, adjustment and the immediate test reactions to the problems on presentation.

4.Concluding Statement

A major shift in thinking is apparent. It converges on specificity in the formulation and reformulation of problems more and more productively in the phraseology of Gestalt psychology. This point of view or approach to the problem facilities studying experimentally the varied processes of

thinking which lead to the development of understanding, generalization, discrimination, concept development and attainment. This initial spin off gain is not easily seized because, as already mentioned, it is easier said than done. The main reason appears to be that the researchers, on the one hand, and the practitioners, on the other hand, both placed in different settings, do not necessarily ask the same question. These split questions are bound to appear in the business of any science, psychology being no exception. It is then not a case of despair, for the solution to the problem then lies in considering the two problems separately as is frequently done in the case of certain anomalies in science. However, when answers to the split questions are mastered successfully, one after another, the whole field over the years becomes quite explosive. The area of creativity is a case in point. Thus are answered the most fundamental questions in science. The basic problem here is to relate the most powerful concepts of science to the intellectual development of children. The psychological structure of any school subject depends upon the answer to this basic problem. The present study is an attempt in that direction.

Lastly, whereas the whole area is full of problems, the latter now lie more in the zoo rather than in the jungle. Thanks to the recent research efforts of Ausubel, Bartlett Bruner, Flavell, Gagne, Guilford, Hans Furth, Humphrey, Inhelder, Lovell, Lunzer, Peel, Piaget, Schwab, Skinner,

Suchman, Vernon and Wallace, a few among many noted workers in the field, it has become possible to pose specific problems in this area which was, however, not the case over twenty five years ago. This survey succinctly tells that psychological concepts do not, develop in a vacuum for children live in environments; physical, mental and social. They learn formally, informally; and equally possess personal knowledge about men and matters. How is then their thinking generalized at various age levels in apparently different psychological constructs? is a very basic question yet in search of satisfactory answer. Like the proverbial five blind men, the whole elephant has to reconstructed bit by bit again and again. Our miserable failure on this front has deprived us of any worth-while psychological structure for any one of the school subjects, at least, in this country(148). Several specific studies are needed whose answers over the years are bound to illumine the very basic of the likely emerging productive frame of reference. The solutions to these problems may not be very far off, yet they also, at the same time, equally lie currently beyond the nose. To conclude on an optimistic note, efforts in this enterprise are going to be more successful than in the past. At the same time, it is also equally stressed that the whole field of human thinking which is as vast as humanity itself throws up quite a few fundamental problems which are yet to be investigated even partially before we can fully understand the basic assumptions underlying human thought processes. And the latter, in turn, are also open to continual scrutiny.

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